COMMUNICATION AND NAVIGATION TRAINER DEVICE 1D23

CDR J. A. GASH
Flight Training and Operations
CNET Staff
and
Mr. D. R. Hayworth
Simulation Systems Engineering
General Electric Company

Communication and Navigation Trainer Device 1D23 was introduced into the Naval Flight Officer (NFO) training syllabus in November 1972. A second phase in this acquisition was completed in August 1974 with the incorporation of the digital Electronic Radar Navigation subsystem. Through the joint efforts of the Naval Training Equipment Center, NAS Pensacola training cadre, and General Electric's Ground Systems Department, installation and operation for each phase was achieved on schedule. A new medium has been implemented to provide Naval Flight Officer trainee and instructor personnel with a real-time dynamic training environment through the employment of digitally controlled simulation.

The trainer is being used to develop NFO skills and techniques in the accurate use of airborne communications and navigational aids. Individual training and evaluation is conducted for up to 40 students simultaneously. Each Trainee Station represents a separate aircraft, capable of independent maneuvering within a given training area. Two unique preprogrammed missions can be employed simultaneously, one mission for each group of 20 students. Generally, one instructor and two Training Device Operators (TDOs) are utilized to direct/monitor each group of 20 students during a training session. NAS Pensacola training cadre employ all available trainer functions to fully exercise NFO students in the Comm/Nav tasks encountered in operational aircraft. This trainer is the first of its kind to be fully operational and offers a new dimension in real-time digital radar display simulation. The innovative techniques employed in Device 1D23 provide state-of-the-art simulation now, while accommodating future technology and requirements growth. A portion of the Device 1D23 trainer is depicted in Figure 1.

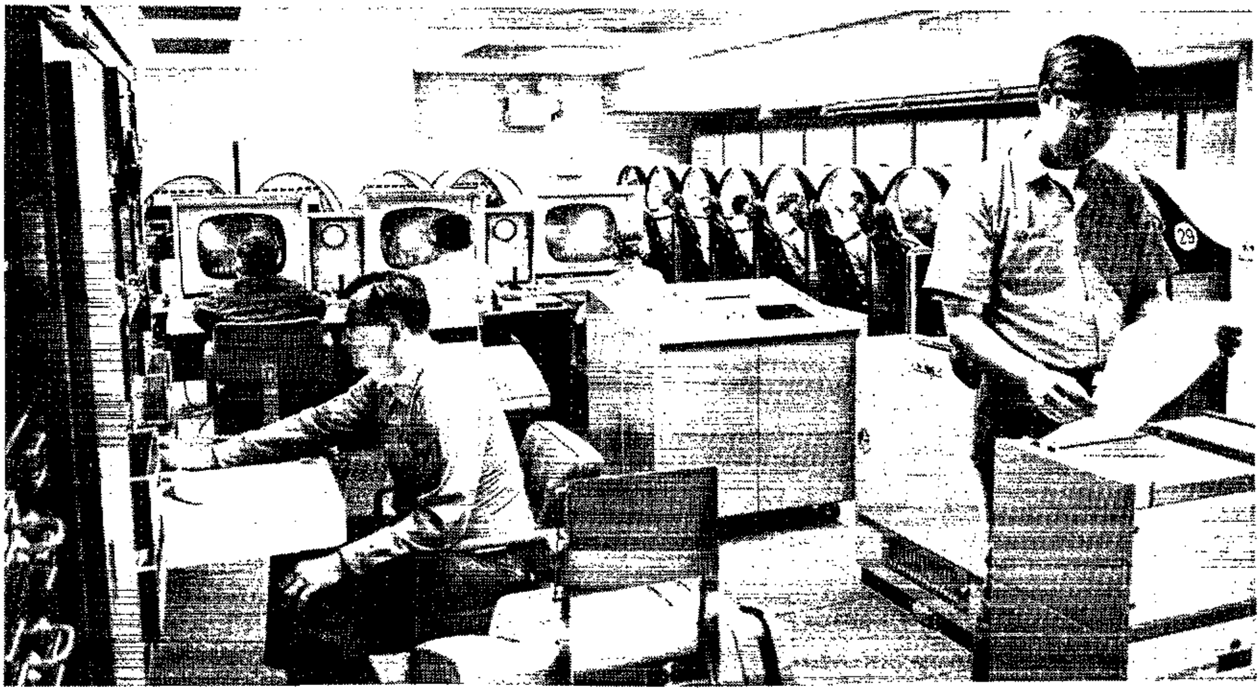

Figure 1. 1D23 Training Room

FUNCTIONAL DESCRIPTION

Device 1D23 is composed of 40 trainee stations, each equipped with flight instrumentation and displays to provide a realistic cockpit environment. Student stations are grouped into four sets of ten, with each group assigned to a separate Trainee Computer. Control commands generated by the Trainee Computer relate directly to each student's response as he navigates his aircraft over a planned mission course. The computer continuously calculates and updates the aircraft's position, cockpit instruments and applicable displays for each trainee. A digital communications unit implements computer commands and provides for recording and playback of the trainees performance, as applicable to their practices of communication skills. Instructional cues and queries are presented to the student, via an Annunciator panel, as the mission progresses. Trainees enter responses and aircraft control data by using a Command/Response panel. Some 24 alarm or warning messages relating to aircraft systems operation can be presented to the student for appropriate action. Each Trainee Computer also interfaces with ten radar processors. Thus, aircraft position data is used by the radar processors to simulate the precise radar images along the planned route.

Performance data for each student is continuously transferred by the Trainee Computer to an Instructor/Operator computer for display and recording. Either of two Instructor/Operator computers provide executive control to two Trainee Computers and a programmable display computer. Trainee performance profile data, which is recorded during the mission, is prepared for output on a line printer in the form of a post-mission printout. Each hard copy profile includes a ground track plot that is generated for comparison of the student's track to that of an ideal navigator. All trainees are automatically scored, then evaluated with others flying the same mission.

Basic dead reckoning, inertial, doppler, and radar navigation techniques are developed and refined by flying simulated missions. The Trainee Computer integrates all navigation systems, as well as the attitude reference and magnetic compass systems, into the total navigation problem and solution. All instruments are updated and respond as though the trainee were in flight.

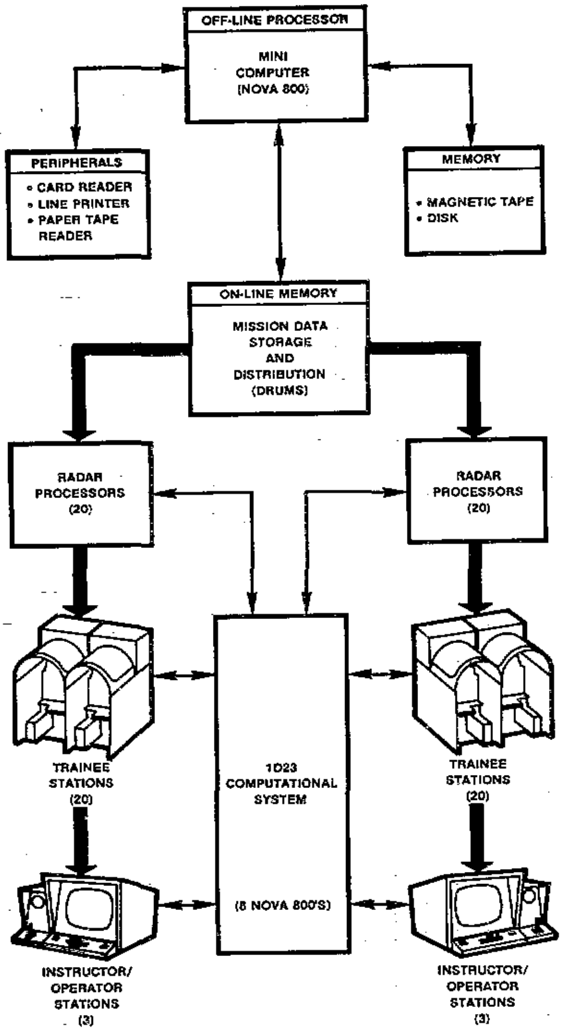

Figure 2. 1D23 Functional Diagram

The trainer's principal hardware elements are shown in Figure 2. The following listing indicates the major system components including significant features:

- Eight general-purpose minicomputers with a total core memory capacity of 160,000 data words are configured into a computational system, via a Multiprocessor Communications Adapter (MCA). The MCA permits blocks of data to be transferred between computers through the individual data channels of each computer.

- One general-purpose, minicomputer with 32,000 words of core memory is used for off-line radar data base processing and drum loading.

- 40 radar processors that provide the processing and transfer of data base elements as a function of individual trainee station geographical position.

- Five disk packs which provide for mass storage of approximately 6.25 million, 16-bit data words (includes preprogrammed missions, constants, diagnostics programs and the student performance profiles acquired during each mission).

- Two drum units that provide for mass storage of the 1D23 data base (approximately 3.25 million, 16-bit data words). Contents of each drum are transferred to the Radar Processors every 538 milliseconds.

- Training room line printer provides hard copy record of each trainee's performance profile for a given mission. Retrieval and print time for 20 student profiles, including overlaid plot of student versus ideal navigation track, is approximately 5 minutes.

DIAGNOSTICS

Device 1D23 utilizes on-line and off-line computer diagnostics to enable rapid problem identification and fault isolation. To facilitate on-line problem identification for the instructor, two types of diagnostics are available:

- Computer Master Controller programming automatically compares correctly functioning group of logic with an identical string of logic that is faulty. This function rapidly identifies general problem areas for instructor/maintenance personnel.

- Test patterns are available to check operation of critical radar presentation elements (i.e., weather effects, terrain content, direction orientation, target points, etc.).

Comprehensive off-line diagnostics provide fault isolation capabilities down to the component level. The skilled maintenance technicians can effect most repair/replacement actions in a matter of minutes, thus minimizing trainer off-line time and assuring essential training schedules are met.

TRAINEE STATION

Various instrument, control, display, data entry, and non-aircraft related equipment that comprises a Trainee Station is depicted in Figure 3. Under computer control, this equipment provides training in the following:

- Basic communication techniques (UHF) and utilization of IFF/SIF systems.

- Basic dead reckoning.

- Navigation through ground-to-air Nav Aids (TACAN and VOR) and utilization of DME, RMI and ADF equipment.

- Advanced navigation (inertial, doppler, air data and computer).

- Proper integration of navigational disciplines.

- Relative motion problem solving.

- Fuel management.

- Radar display and controls.

- Cursor intersection and radar-directed navigation.

Non-aircraft related equipment enables the student to respond to commands, control aircraft performance, receive instructions, and obtain knowledge of results.

INSTRUCTOR/OPERATOR CONSOLE

The Instructor/Operator Console (IOC) arrangement is shown in Figure 4. As pointed out earlier, Device 1D23 can be set up to permit all 40 NFO trainees to fly the same mission or it may be operated in such a manner as to allow two groups of 20 trainees to fly different missions, each under the cognizance of one instructor and two TDOs. Two IOCs are used to conduct/monitor the training of 40 students and each IOC can serve an instructor and/or the TDOs. Graphic and Radar CRTs provide visual data (alphanumeric and pictorial) in four basic system operating modes. Mode selection is accomplished by the instructor and enables the following:

- Daily readiness testing.

- Problem setup.

- Problem control and monitoring (5 submodes).
- *Post-mission playback.*

The IOC control and display devices permit the instructor to continuously monitor student performance, provide rapid assistance at times of overt student actions and enable the TDOs to provide simulated ground communications to the trainees.

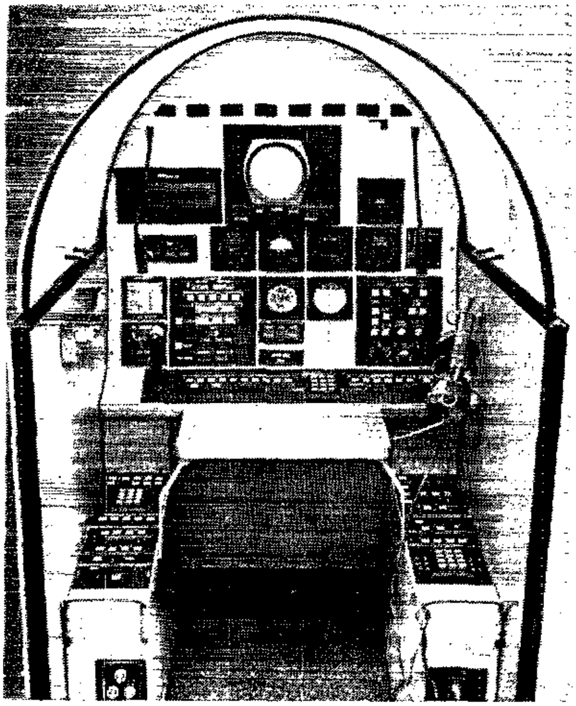

Figure 3. Trainee Station

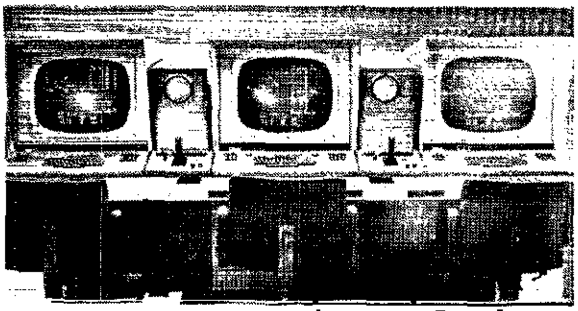

Figure 4. Instructor/Operator Console

RADAR NAVIGATION SUBSYSTEM

The basic data flow for generating landmass video for a single trainee station is depicted in Figure 5. The total 20° by 20° data base training area is stored on magnetic tape. Upon selection of a training mission, the computer loads that portion of the data base required to support the mission onto the storage drum. Since two independent mission storage drums are provided, two separate missions can be flown simultaneously by each group of twenty students or all forty students can fly the same mission. In each case, the student has independent control of his aircraft's flight path. Computer monitoring is provided to alert the instructor should any student wander too far from the planned flight path.

Once the selected mission (or missions) is loaded, the system is ready for training. In operation, the total contents of the mission drum are read into each trainee station radar processor continually. Each data word on the drum is tested based on the individual aircraft position and range selection to select that data which is applicable to the current radar scan. Only those data words defining features within ±45° of the aircraft heading and within the selected radar display range, plus a buffer zone to accommodate aircraft motion during the scan period, are accepted and placed in the scan memory. There are two scan memories for each radar processor that alternate between read and write modes. While one scan memory is being loaded with new data, the second scan memory is being accessed by subsequent stages of processing. At the end of each drum read cycle, the modes of the two scan memories are reversed.

The next stage of processing selects, from the scan memory data, that data within a small scan segment about the current antenna azimuth angle. This is accomplished by testing each word in the scan memory and only retaining for storage in the segment memory those words necessary to define the segment of interest. There are two segment memories that alternate between read and write modes at the end of each scan memory read cycle similar to the scan memory operation.

The final stage of data reduction selects from the segment memory those data words defining features that intersect a single sweep line or lie within half the radar beamwidth of the current sweep line. All other data words are discarded. The ground range and elevation at which each remaining feature intersects the sweep line are computed and then these are sorted into increasing ground range order to construct a terrain elevation profile and reflectivity profile along the sweep line. This ordering process is necessary because data intersections are computed in the sequence in which the data was loaded into memory without respect to distance from the aircraft position. Two memories are also utilized at this stage of processing and alternated as described previously.

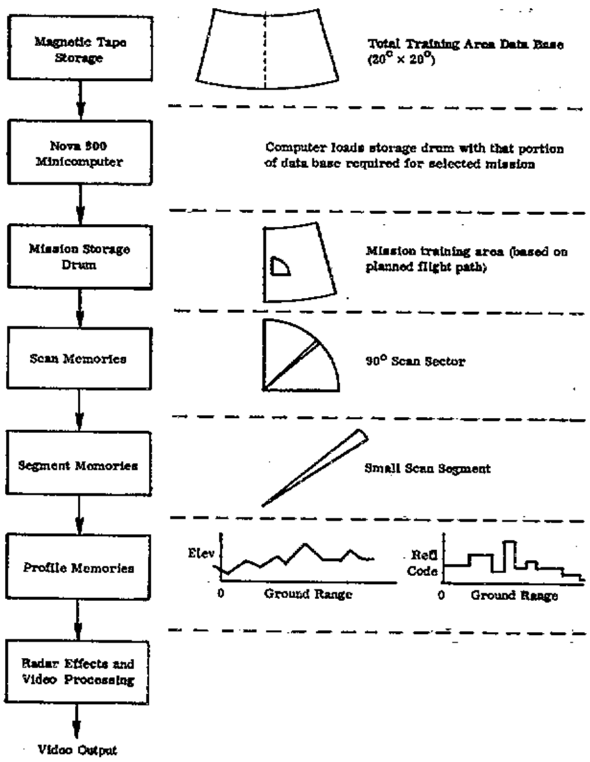

Figure 5. Radar Landmass Video Data Flow Diagram for One Trainee Station

Special geometric and radar effects are then added as these profiles are read on an element-by-element (ground range) basis. During this process, the slant range is computed, and the reflectivity codes are converted to 8-bit digital power levels. These levels are then attenuated according to radar control settings and geometric factors to generate a video signal on a sweep-by-sweep basis. The resulting landmass video signal is displayed at the associated trainee station and can be monitored by the instructor.

As the aircraft moves through the data base and the student adjusts the radar controls, the displayed video reflects those adjustments. Training is therefore provided for both radar picture setup as well as basic radar navigation.

DIGITAL DATA BASE

The digital data base is the set of numerical data that represents a geographic gaming area for which simulated radar images are to be produced. The quality of the resultant radar simulation is directly dependent on the quality (fidelity) of the data base. The cost of both simulation equipment and of data preparation increases as a function of the amount and quality (resolution) of information in the data base.

Accordingly, the basic design objective for data base development was to provide simulation of the required quality with a minimum quantity of data. This objective was satisfied by a variable-compression data base technique that allows high data densities in areas having high radar information content without requiring similar amounts of data in areas of low information content.

The principal features of the data base environment modeling techniques follows:

a. Planar surfaces are used to approximate the geometry of the terrain. These planar surfaces are defined by line-segments (vectors) called boundary lines. The crossing of a boundary denotes a change in slope. These boundary lines can also be used to denote a change in reflectivity with or without a change in slope since the data word for a boundary line contains information of reflectivity to the left and to the right.

b. Individual data points are used to represent isolated objects, such as towers, power pylons, and other similar cultural objects. These data points are called point targets. Point targets have assignable radius, height above terrain, and reflectivity.

c. Line segments are linked to define elongated (lineal) features, such as bridges, highways, and levees. The width, height above terrain, and reflectance level of such lineal features are assignable. These data base elements are called line targets.

Each data point (i.e., point target, vertex of a line target, or planar segment as stored in the memory) carries lateral location and elevation (height above terrain for lineal and point features) values. The coordinate location of each data base word is defined with respect to the previous word, and therefore, data base words can be considered to represent vectors. These vectors are used to define planar segments that approximate the terrain relief and to outline radar significant cultural features.

To provide a simulation of the improved radar resolution obtained for decreasing range settings, the data base is composed of multiple digital radar maps. Digital radar maps are utilized to support the 30, 60, and 120 nautical mile range settings. The digital radar maps for the shorter radar ranges contain considerably more information than the digital radar maps for the longer ranges. This is in direct correspondence with the radar's resolving power (i.e., shorter pulse widths on the shorter ranges). It also corresponds directly with the resolvability of the radar display scope (i.e., the scope spot size).

The quality of the data base is dependent upon both the source material used and the accuracy of the process which transforms this data to the radar format. The source materials utilized in the production of the radar data base for Device 1D23 consisted of the medium scale 1:250,000 topographic charts and the corresponding TOPOCOM, Digital Terrain Elevation Tapes.

ABOUT THE AUTHORS

CDR JOHN A. GASH has been a commander of the Flight Training Section on the staff of the Chief of Naval Education and Training since October 1971. During this time, Commander Gash has closely monitored the introduction of new air training devices into the Navy's Undergraduates' Flight Training Program. These devices include the 2F90 and the 2F101, which simulate the flying qualities of the A-4 and the T-2 aircraft, respectively, and the 1D23 Communications/Navigational/Radar Trainer used in the training of prospective Naval Flight Officers. As a Naval Flight Officer, Commander Gash has had the following previous duty assignments:

- *Airborne Early Warning Squadron 11 - Argentia, Newfoundland*
- *Navy Hurricane Hunter Squadron, Jacksonville, Florida and Roosevelt Roads, Puerto Rico*
- *NATTC Glynco, Instructor*
- *USS ENTERPRISE (CVA-65(N))*
- *VAW 123 E-2 Squadron aboard the USS SARATOGA (CVA-60)*

MR. DONALD R. HAYWORTH is currently the lead systems engineer on two General Electric digital radar landmass contracts. He received his B.S.E.E. degree from Texas Technological College in 1960 and his M.S.E.E. degree from the University of Florida in 1969. During 1963 to 1964, he was responsible for the simulation of the major Apollo Command/Service Module subsystems to analyze crew procedures for the various Apollo missions. From 1965 to 1972, he led and supported digital radar landmass and computer-generated image research and development projects leading to an operational laboratory simulator, study contracts leading to system specifications and contract follow-on, and mathematical modeling technique development studies.