# SIMULATION OF MODERN RADARS IN FULL TACTICS SIMULATORS

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ABSTRACT

The correct use of modern radar in flight and attack aircraft is one of the main tasks of the pilot and copilot. This means that training in radar operation and image interpretation is one of the most important training aspects in a full mission simulator. Realistic simulation of modern radars is essential to achieving the required training.

The state-of-the-art in micro-electronics, data processing, computer graphics and other relevant areas make it possible to generate all necessary radar signals in real-time using completely synthetic video generation methods. Based on digital data bases and the appropriate aircraft and radar parameters, terrain and culture profiles are generated. From these profiles, radar echoes simulating Ground Mapping Radar, Terrain Following Radar and the Radar Altimeter are synthesized. Typical radar effects such as range attenuation, shadowing, far-shore enhancement, and pulse stretching are accounted for along with the antenna, transmitter, and receiver characteristics of the actual radar in all operating modes.

The radar simulation is performed in real-time, with all computations up-dated at a rate consistent with the radar characteristics and the flight control system of the aircraft. The use of a high up-date rate allows all training missions to be performed with full freedom of manoeuvring in the simulator.

This paper describes the performance characteristics of a Digital Radar Landmass Simulation System (DRLMS), developed for the TORNADO Flight and Tactics Simulator, with an emphasis on its training role.

## INTRODUCTION

The European Multi Role Combat Aircraft Tornado is equipped with one of the most modern and sophisticated Radar systems. The system has been developed by Texas Instruments. For the Tornado Operational Flight and Tactics Simulator the German Air Force and Navy as well as the Italian Air Force have decided to adopt a Digital Radar Landmass Simulation System developed by Messerschmitt-Boelkow-Blohm, Dynamics Division with certain know how inputs from General Electric, SCSD Division, Daytona Beach, Florida.
In the meantime the first two systems have been accepted by the customer.

## RADAR SIMULATION OF MRCA

The primary function of the Multi Role Combat Aircraft (MRCA) Digital Radar Landmass Simulation (DRLMS) is to provide realistic simulated radar display video for the ground mapping radar (GMR) and terrain following radar (TFR). The simulated radar video is subsequently presented on the operation/maintenance station radar display and the MRCA Operational Flight and Tactics Simulator (OFTS) simulator system displays. Simulated video is also generated for presentation when either the contour mapping on-boresight (CMO) or target height finding (THF) mode of the GMR is selected. As selected by mode, the content of the simulated video includes a predetermined combination of terrain and culture returns, environmental and mission effects, jamming and noise interference, air and seaborne target skin paint returns, and beacon code video.

The format of the DRLMS simulated video output is compatible with the MRCA-OFTS interface for each of the varius operating modes of the MRCA nose ground map radar set and the terrain following radar.

Other functions of the MRCA DRLMS subsystem include the altimeter radar, the occulting of fixed site and moving platform threats, incorporation of mission and environment effects, generation of thunderstorm or chaff backscatter and data base up-dating.

Principal features of the MRCA DRLMS subsystem include European gaming areas, accurate terrain and planimetry data for each radar pulse width and on-line data storage capacity for a minimum of 5,000.000 square kilometers (1,500.000 square nautical miles).

## MRCA-DRLMS

The Digital Radar Landmass Simulator (DRLMS) is a subsystem of the Multi Role Combat Aircraft (MRCA) Operational Flight and Tactics Simulator (OFTS). The DRLMS in the OFTS is shown in Figure 1.

Interface data from the MRCA-OFTS that define the current aircraft position, radar control functions and the threat, weapon, beacon and jamming requirements of the mission are supplied to the shared core memory portion of the MRCA-DRLMS computer. Interface data from MRCA-DRLMS that define the GMR-Video and TFR-Profil are supplied

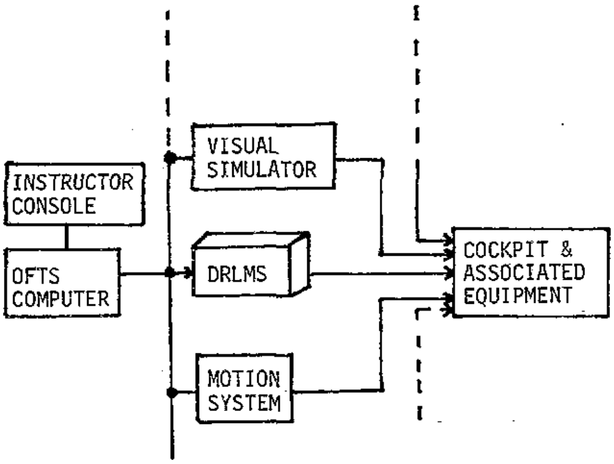



Figure 1: DRLMS in the OFTS

to the simulator cockpit, altimeter- and threat occult-data are supplied to the OFTS main computer.

The physical system configuration is shown in Figure 2. The major equipment items that comprise the MRCA-DRLMS are the DRLMS-Computer system (CPU, tape, 3 discs, terminals and printer), the DRLMS-radar processor with the power control and the operator/maintenance station (operator/maintenance console with a summagraphics digitizer tablet, graphic/alphanumeric terminal and hard copy unit).

The system function block diagram (Figure 3) is helpful for explanation of the DRLMS function. Figure 3 shows the system block diagram with the principal data flow represented by solid lines, and the basic control functions represented by broken lines.

Interface data from the MRCA-OFTS that define the current aircraft position and radar control functions are supplied to the DRLMS computer. Regions of real-time digital data are selected as a function of aircraft position and read from one of three 300 megabyte disc units.
The selected region data are stored in the DRLMS region memory. The regions stored there are for the long-, medium- and short-range data bases. A square set of region is selected about the aircraft home region at the mission initial point for each data base.
Thereafter, the active real-time data base is updated by deleting regions out of range because of aircraft movement and by adding new regions which are presently within range of the radar. This is accomplished each time the aircraft crosses a region boundary and thereby enters a new home region. Refer to Figure 4 for typical region update geometry. In addition to the region data, the real-time data includes dynamic target and occulting data from the OFTS-computer. These data are sent by the DRLMS-computer to the moving target memory. The moving target memory is also holding weather and chaff data as established by the OFTS instructor selection.

The data base processor includes region selector, segment stripper and segment memories. Segment data are selected from the region memory by the region selector in the region controller. Radar return response data for point targets in the word format are target identity, directivity, reflectivity, and target width. Radar return response data for culture edge word contain reflectivity and edge type identity. Terrain edge words carry no reflectivity. The weather code replaces reflectivity for weather and chaff edges. For beacon, dynamic target data, a beacon code is included. For dynamic (or point) targets, the return is dependent on the cross-sectional area code.

Figure 5 illustrates the home region of the aircraft and the surrounding 8 regions that are always read by the region selector. The reminder of the regions selected grossly approximate the segment width to be stripped ($\Theta_{S2}$).
The segment stripper tests reduce the data to that pertinent to the segment width ($\Theta_{S2}$) for storage in the segment memories.

The data word type and X/Y position is used by the segment stripper in determining which edges and targets (points) are to be selected for each simulated antenna scan segment. All GMR and ALT edge or point words, passing the segment tests, are stored in a common active edge ping-pong memory. A separate memory is maintained for TFR or TOP data. Each unique memory segment of data contains the data for the next set of scan lines.

The data sorter provides three functions (intersection processor, intercept orderer, and priority resolver and data profile storage). The intersection processor determines points of intersection on the process sweep line. In so doing, it converts the X, Y, Z cartesian vertices received from the second memories to range (R) and Z coordinates at the process sweep line angle of the intersection processor. These converted data are ordered from near range to far range by the intercept orderer. Then, the data culture is resolved by priority number where conflicts exists for which data are to reside in a particular range process element of the process sweep line. Then resolved data are stored except for weather and chaff. These data are sent direct to the weather processor. The terrain data are processed and stored and require no priority resolution because terrain data carries no reflectance.

The power processor includes natural effects processor (NEP), weather processor (WEP), altimeter processor (ALT), terrain following radar processor (TFR) and target occulting processor (TOP). The ground range ordered terrain profile and culture profile are output from the data sorter to the natural effects processor. The natural effects processor determines the slant range and angle of incidence relative to the radar antenna (aircraft position) above the earth for each successive simulation pointing angle of the radar antenna. Using this data and transmitter power,

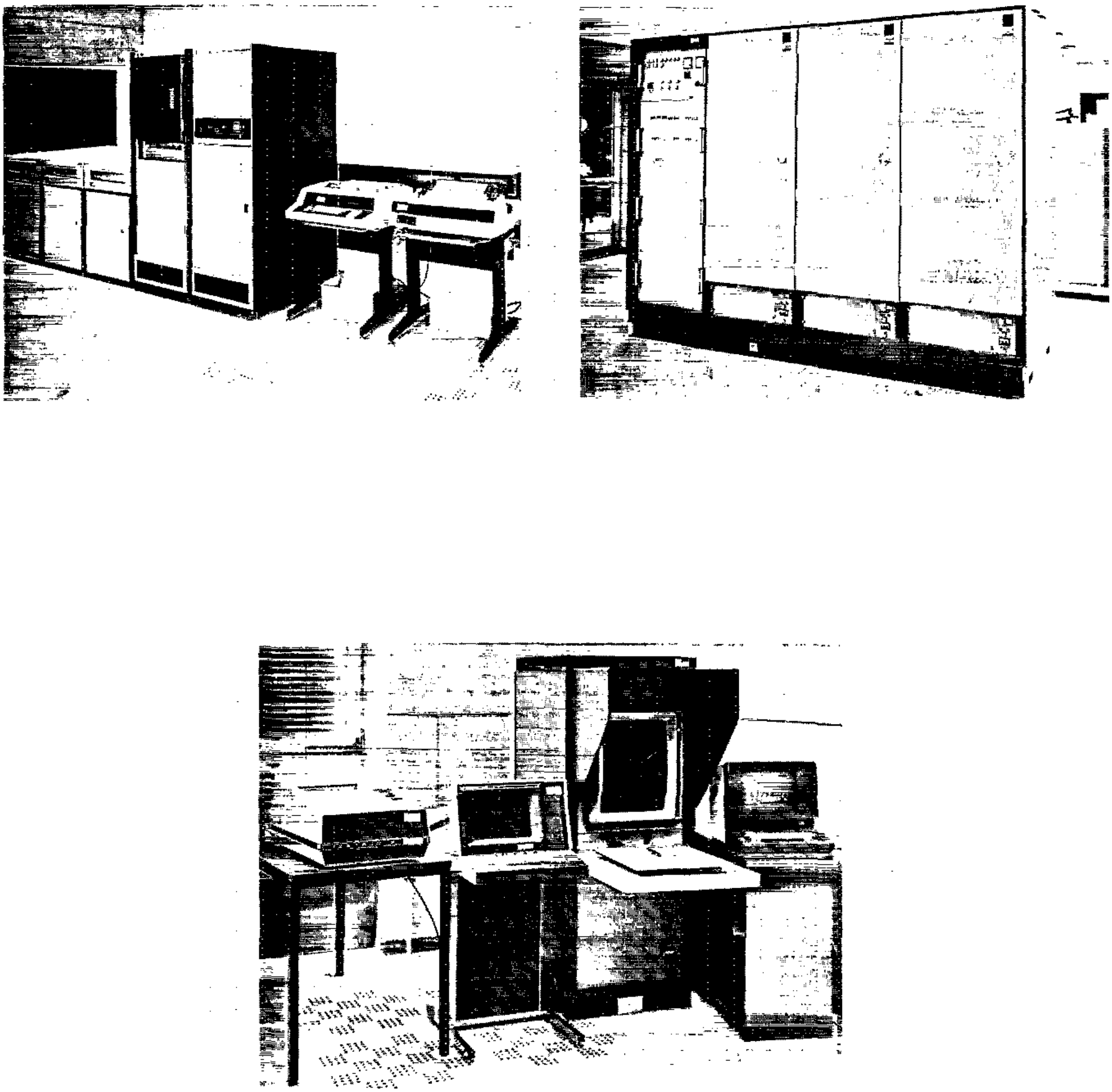


Figure 2: MRCA DRLMS System Configuration

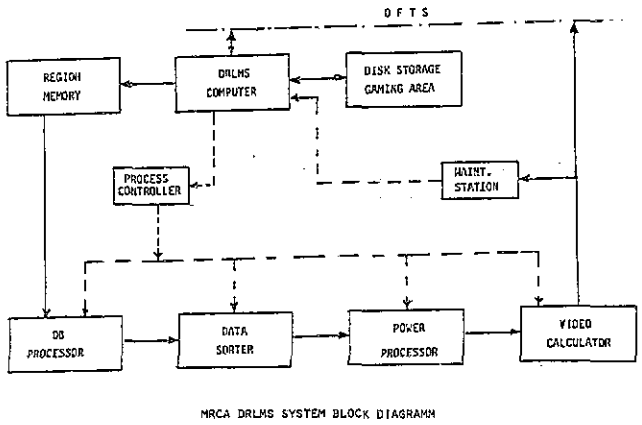
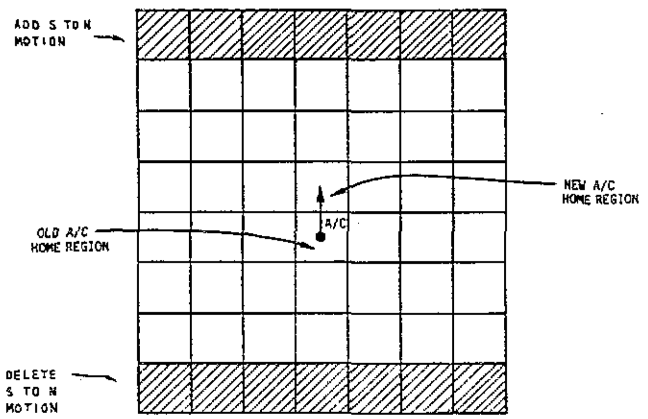



Figure 3: MRCA DRLMS System Block Diagram



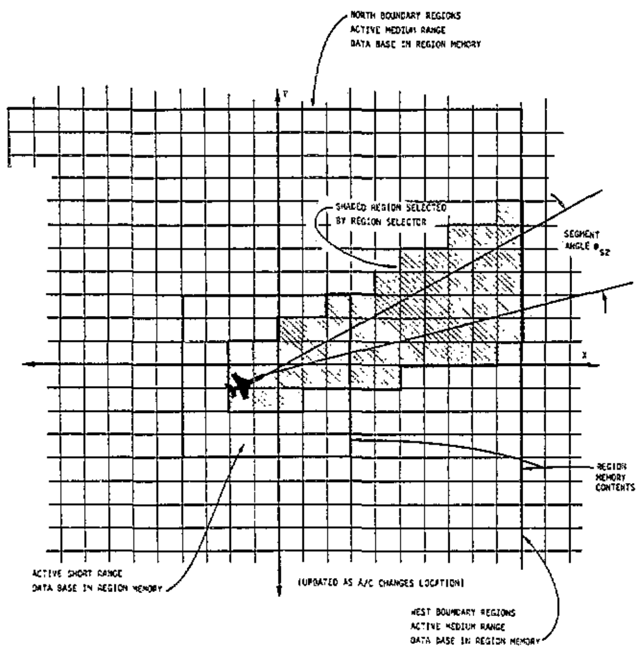




Figure 5: Region Map of Data Selected by Region Selector and Segment Stripper

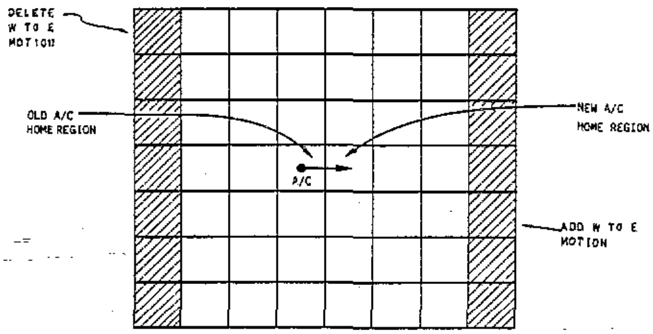



Figure 4: Typical Region Up-date Geometry

antenna gain and assigned backscatter coefficients in the culture reflectance codes or weather data codes, the natural effects function determines the solution of the radar return equation. Four versions of this equation are used to provide for areal target returns, point or line targets returns, *weather returns and beacon or jammer re-*turns. Radar shadow flags and special effects such as fare-shore enhancement, and sea state are added. These returns, in decibels (dB), are sent to the radar effects processor along with the slant range (SR).

The weather/chaff processor provides weather/chaff backscatter return levels and weather atmospheric attenuation for all GMR modes, and the ALT and TFR mode cycles. The weather/chaff processor is not required for TOP functions.

For altimeter (ALT) radar simulation, the altimeter radar return, simulator portion of the natural effects processor tests are calculated return level in the 360° altimeter antenna field of view about the aircraft and saves only those that are above the altimeter radar receiver sensitivity threshold. A further test saves the first return with the nearest slant range in the field of view. These data are output to the OFTS computer.

Terrain following radar (TFR) information selected from the medium-range active real-time data base is furnished to TFR processor by the natural effects processor (NEP). These data are subsequently slant range ordered and are accumulated for 6 consecutive TFR scan line segments to obtain an average power level for the TFR antenna field of view. Upon completing the sixth iteration of the order and accumulate process, a TFR slant range ordered profile is generated as a function of the accumulated data, that is output to the OFTS interface and the video controller portion of the video calculator.

The threat occult processor (TOP) provides 2 functions:

(1) computes the effect of jamming for up to 4 threats that are identified as being jammers *and*

(2) records the occult status for up to 64 threats.

The threat data includes the occult status elevation above mean sea level and threat/weapon identification number. The TOP performs the necessary calculation to determine the occult status of each threat target. These data are identified by threat target ID number from input to the moving target memory until it is returned to the DRLMS computer. The TOP provides jamming information to the GMR video channel for each GMR sweep output. Jamming simulation data are also provided for each TFR sweep.

The video calculator includes the radar effects processor (REP) and the video controller (VC). The radar effects processor (REP) receives the radar return dB levels and slant range for terrain/culture, dynamic targets, weather and chaff, and beacon from the natural effects processor (NEP). The beacon code, beacon flag, glitter flag, and CMO flag are also received from the NEP. The terrain/culture dB is slant range ordered, including airborne target dB. Weather is independently slant range ordered. The pulse width error (or pulse width integration effects), horizontal beamwidth integration, beacon, jamming, receiver noise, radar receiver characteristics, sensitivity time constant, and conversion from *dB to volts are than accomplished. The output* is at the operating bandwidth resolution for display output to the video controller. Jammer dB levels and jammer type identifying flags are received by radar effects from the target occulting processor.

The video controller (VC) receives the video levels in volts and in digital format from the radar processor. The video is digital-to-analog (D/A) converted and is processed to output GMR video to the OFTS. Either GMR or TFR outputs may be selected for display on the maintenance console.

Functional control of the DRLMS is directed from the process controller (PC). The process controller function contains a control oriented computer (CORC). The CORC synchronizes and directs all of the DRLMS computer/processor activities. It accepts radar parameter and aircraft data from the DRLMS computer. The OFTS computer provides dynamic control data for the radar control parameters to the DRLMS every 55 msec. This information is than distributed to the applicable functions in DRLMS, in a manner that is transparent to the OFTS system operators. The CORC is a fixed program, interrupt-driven device. Fundamental to the pipeline process timing in the DRLMS is the selected operating mode and pulse repetition frequency (PRF) of the radar. Also function of the operating mode is the effective *antenna scan rate. The PRF established the time* between radar sweeps and, thus, the angle between sweeps for a given PRF and scan rate.

The DRLMS computer/processor has two fundamental operating modes: On-line and off-line. Selection of the operating mode is accomplished by the operator at the DRLMS operator/maintenance station. Data base up-date and diagnostic and maintenance operations are conducted in the off-line operating mode. The diagnostic data base for these operations is stored on a dedicated portion of one of the 300-megabyte discs. Control of the DRLMS subsystem for the off-line operating mode is exercised from the operator/maintenance console.

The method of data base modelling is of critical importance in establishing the DRLMS design approach.

The digital data base is a set of numerical data that defines the terrain elevation and the radar significant features on the earth surface for a given geographical areal, which is prefered to as the gaming area. The realism possible from a radar simulator is directly dependent on the quality (or fidelity) of the digital data base, for without a valid discription of the gaming area the best of software and hardware cannot create a realistic radar image.

The data capacity of the DRLMS for the on-line data base is sufficient to store at least the data of a 5 million square kilometer gaming area. Out of a 1.996 x 1.996 nm square an arbitrarily gaming area may be choosen. MRCA DRLMS real-time radar data base boundaries are shown in Figure 6.

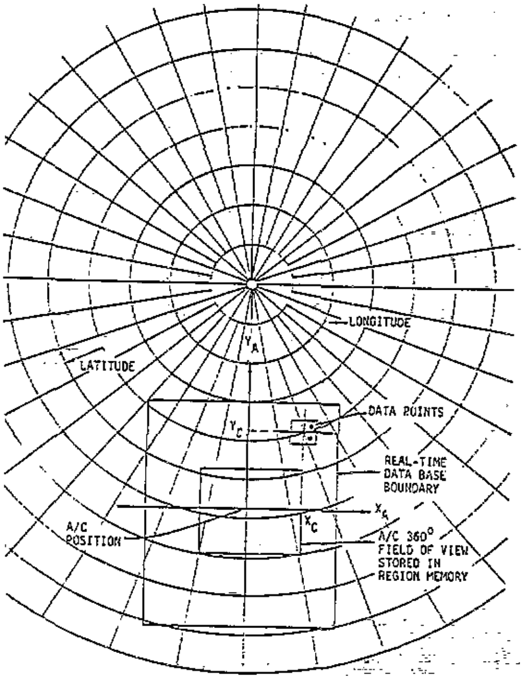



Figure 6: Aircraft 360 Degree Field-of-View in Real-Time Radar Data Base

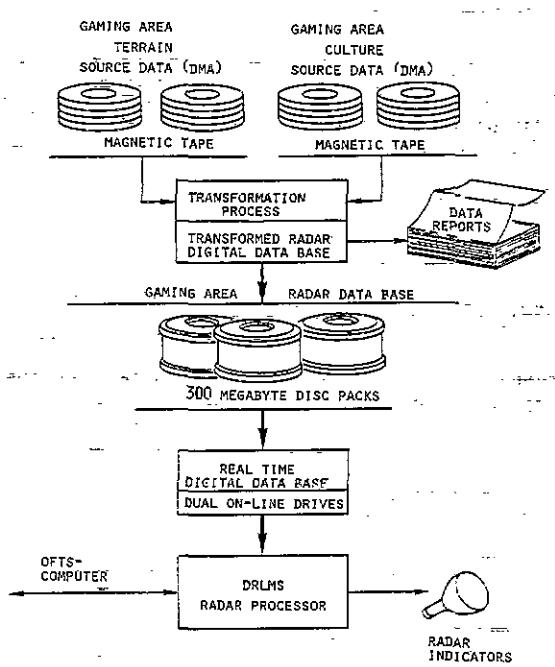



Figure 7: Radar Data Base Flow

Transformation of defence mapping agency aeronautical center (DMAAC) terrain and planimetry source data and merging of these transformed data into a single radar data base file are accomplished by the transformation program. The transformation program is fully automatic implementation of the terrain and planimetry compression technics described. Three digital data base maps (DDM) are generated, one for each level of resolution to be simulated. Each DDM defines both the terrain elevation and radar reflectivity for the entire gaming area. Radar reflectivity is defined in terms of a reflectance/texture code associated with each discrete radar point/line target and each bounded (areal) target. Target reflectivity codes, 32 for point/line targets and 32 for areal targets, are assigned by the transformation program as a function of a DMAAC feature identification codes. These feature identification codes describe all features in the planimetry file with descriptive information set characterizes the feature in terms of its surface material, e.g. matter, stone/brick, water, snow/ice, trees, rock.

The final step in generation a transformed DDB+) from the DMAAC source data is to concentrate the separately generated terrain and planimetry files into a single DDB file for each DRLMS region of the gaming area. This process consists of merging the two files to a single disc pack or tape, as required. The output of the merge process is the transformed digital data base. Figure 7 summarizes the data base data flow, processing and storage.

## CONCLUSION

Since the Trainings Simulator for Tornado is used as a Full Mission Simulator the system is equipped with a Computer Generated Image Visual System (CGIVS) in order to train among others weapon delivery and position up-dating by means of the head-up display. Necessary correlation of information presented by DRLMS and CGIVS is achieved by common source material used to generate the data bases. The source material is cartographic information in digital form (DMA-format). By means of a data base generation system under development for the German services CGIVS and DRLMS data bases will be created.

+) DDB - digital data base

## ABOUT THE AUTHORS

Lt.Col. Manfred HAAS is assigned to Headquarter, German Air Force, Director Air Armament stationed at Cologne where he is the officer responsible for simulator requirements. He has worked on the following simulator programs: F-104, F-4F, RF4E, Alpha Jet and Tornado. He played an active role in evaluation of the digital visual system and radar system for the tornado training simulator. Lt.Col. Manfred Haas was formerly an active F-104 pilot.

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