THE INFLUENCE OF FULL-MISSION SIMULATION ON VISUAL SYSTEM CAPABILITY

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In evaluating the prototype full-mission simulator for Western Germany's multi-role combat aircraft, the PANAVIA TORNADO, important experience was gained in determining the degree of quality demanded of the visual system by this type of simulator.

The role of the TORNADO as the principal battlefield interdiction and strike aircraft for the West German military required pilots to maintain a high degree of combat readiness for a multitude of tactical situations. Four Air Force and two Navy wings should be operational by 1985 and the overall program calls for each wing to be equipped with a full-mission simulator capable of performing a degree of realism never achieved before in simulation within the German Air Force. The simulators are to be delivered progressively over a 3½-year period starting in 1981.

Decisive consideration of the TORNADO training program took place during 1975. At that time, state-of-the-art technology in motion systems, digital radar landmass simulation and, in particular, computer-generated visual image systems (CGVIS) indicated that a full-mission simulator was both technically and economically feasible.

A major condition of the TORNADO training program was to develop, integrate and evaluate the CGVIS in prototype form before committing to a definitive technical specification.

The original visual system module had the following performance characteristics:

A. GENERAL CHARACTERISTICS

1. Number of channels - 3

2. Real-time scene capacity (i.e., portion of the on-line data base processable at a given time) - 2000 edges and 1000 point light sources. This represented a total capacity and was shared between 3 channels.

3. On-line data base - 10,000 edges and a minimum of 1000 point light sources.

4. View plane elements - Standard United States video of 525 lines with 2.1 interlace. Of these, 470 lines and 500 elements/lines per display were visible to the trainee.

5. Levels of detail - 8

6. Frame rate - 30/second

7. Color capability - 63 colors, selectable from 16,000,000 hues.

8. Smoothing - Smoothing of discrete raster element steps was provided in the horizontal and vertical direction. This was also applicable to point light sources.

9. The visual system responded to an output from flight simulator interface within 100 milliseconds.

B. SPECIAL EFFECTS

1. Moving targets - The capability was provided to display up to three moving targets at any one time. These were ground/sea targets, air targets and others. These targets were provided within the real-time edge and point light capacity of the system.

2. TV Missile Simulation - In lieu of normal pilot display, a scene representative of that generated by a TV missile camera was generated from the on-line data base for the navigator's display. The scene was unchanged in its timing relationship from that employed in the visual system. The image generator computed the scene with the TV/TAB system from the computed location and orientation of the missile. During this phase of operation, the visual system was required to provide an out-the-window presentation to the student pilot.

3. Special Lighting Effects - Strobe lights, directional lighting such as visual approach slope indicator (VASI), airfield, runway, taxi and approach lights to CAT-II standards and beacon and flashing lights, were simulated in accordance with data base definitions. Lights having recognizable shape or size were made up from edges.

4. Haze and fog - Simulation of runway visual range, fading and cloud base were provided, with the parameters variable under instructor control.

5. Clouds - Cloud base and thickness under instructor control was variable offline. When the simulated aircraft was not in an area covered by a data base, the effect was "as if flying in a cloud."

C. DISPLAY CHARACTERISTICS

Field of view - The total field of view 26° (vertical) by 106° (horizontal) divided into three channels and was designed to fit a maximum amount of the windscreen of the simulated multi-role combat aircraft (MRCA).

2. Contrast ratio - 20:1 minimum

3. Head motion - ± 2 inches (horizontally and vertically)

4. Highlight brightness - minimum of 6 foot-lamberts

5. Display distortion - less than 2%

6. Convergency - The optical system provided a virtual image wherein the rays appeared to converge at a distance greater than 20 meters.

In 1978, this prototype was evaluated by German Naval and Air Force pilots working with program personnel from Messerschmitt-Bolkow-Blohm and representatives from the Technical Directorate of the German Air Force. In performing the evaluation, the pilots exercised the simulator in situations which corresponded with the range of operational maneuvers foreseen for the TORNADO. These situations included:

1. Takeoff and landing

2. En route flight including terrain following

3. Ground and sea attack

4. Navigational updates using head-up display

5. Final phase of air-to-air combat

6. In-flight refueling

7. Formation flying

8. Threat from missile sites

9. Bombing runs

For this purpose, the following data bases were created:

1. Standard air-to-ground range

2. Tactical air-to-ground range (SAM site)

3. Navigational area (Altmuehl Valley)

4. Other aircraft

5. Moving targets on the ground (tanks)

For all missions, adequate scene detail was required in respect to:

1. Position cues

2. Motion cues

3. Object and event recognition

In general, the efficiency of the full-mission simulator concept was proven by the results of the prototype evaluation even though not all parameters of the visual system were fully adequate for all missions.

In respect to the required training tasks, the evaluation showed the following results:

1. Takeoff and landing. This required a presentation of the airport, taxi markings and lighting system by the CGVIS.

a. Taxi - Aircraft on the ground, moved on taxiway and runway to the "hold" markings.

b. Takeoff - Aircraft moved down the runway, accelerated, took off and gained height. Runway markings and the lighting system had to be observed at close distance. The dynamic impression during acceleration would be improved by a detailed presentation of the surroundings of the runway (different colors, buildings, etc.). The actual airport was, therefore, modelled in a high level of detail. The surroundings of the airport (10 x 10 km) were modelled in a lower level of detail. The rest of the whole data base (200 x 200 nm) was modelled in a very low level of detail. This was necessary due to the limitation of the real-time data base (10,000 edges).

c. Approach and landing - same requirements apply as for taxi and takeoff. The lighting system presented by the CGIVS was in accordance with Stanag 3316 including strobes and VASI. The markings on the runway and taxiways were in accordance with Stanag 3158 AML. All required maneuvers could be trained successfully with the existing prototype CGIVS.

2. En route flight included terrain following and navigational up-dates using head-up display. The average height above ground for terrain following missions for the TORNADO aircraft was 200 feet. For flights in accordance to visual flight rules (VFR) the selected altitude was somewhat higher and depended on the weather. The navigations system of the TORNADO required intensive training in the following procedures:

a. Fix-up dating of the navigation system.

b. Input of offset fixes and other non-preprogrammed navigational fix-points.

c. Cooperation between pilot and observer during different phases of fix-up-dating.

d. Terrain following transition from automatic to manual mode.

The data base for en route flying covered an area of 52 x 160 km (Altmuehl Valley). Up to an altitude of 1000 feet above ground, the highest level of detail was selected for the presentation by the CGIVS.

The results of the evaluation showed that the CGIVS prototype could not provide adequate training for these tasks. The resolution of the system (4 minutes of arc) was not good enough for event and object recognition, including navigational fixes. The real-time data base capacity of 10,000 edges was too small to allow allocation of enough three dimensional objects over the whole area of the data base in order to provide the simulator pilot with sufficient visual cues necessary to judge velocity, height and distance. Moving objects could not be presented in this data base due to the limitation of the capacity of the real-time data base.

3. Ground and sea attack - the effectiveness of the CGIVS in this area was evaluated using the presentation of tanks. The attack of tanks using the Bolkow dispenser is one of the major roles of the TORNADO aircraft and should, therefore, be trained with the simulator. The moving objects were integrated with data bases showing terrain.

The evaluation showed that the resolution of the CGIVS was not good enough for target recognition. The number of potentially visible edges to be displayed in one scene (2,000 edges) did not allow for presentation of targets with sufficient realism. An increase in the field of view (106^o horizontal, 26^o vertical) was desired.

4. Final phase of air-to-air combat - was dynamic with a high rate of change in perspective angle of view and a short time available for the required procedures.

It would have been desirable to train the following offensive maneuvers: high-speed yo-yo, low-speed yo - yo, barrel roll attack.

A Fishbed J was integrated in a data base showing terrain. The Fishbed J was modelled in the highest level of detail, but still was not detailed enough to provide the types of aircraft at greater distances when a larger area of terrain had to be shown by the CGIVS.

A higher level of detail could not be present due to the limitation of 2000 displayable edges in one scene. Also the resolution of the CGIVS was not good enough to provide event and object recognition in longer distances. Many of the above mentioned offensive maneuvers could not be trained with the CGIVS due to the limited field of view.

5. Inflight refueling and formation flying. A KC135 was modelled showing the boom of the tanker aircraft. The aircraft and the boom showed all necessary lights and markings generated by the CGIVS. The Fishbed J was used for training of formation flying. Both inflight refueling and formation flying could be trained successfully with the prototype CGIVS.

6. Standard air-to-ground range - bombing runs. The following attack procedures on a standard air-to-ground range were evaluated using the CGIVS: Strafing, rocketry, low-level bombing, low-level slide bombing, dive bombing, visual low-angle drogue deliver (VLADD), backup bombing, and lay down backup bombing. Standard air-to-ground range- Siegenburg Range was modeled for the presentation on the CGIVS.

All performance data of the CGIVS were sufficient for effective training with the digital visual system. Only a larger field of view seemed desirable.

7. Tactical air-to-ground range - Same procedures as 6. above using a tactical target such as SAM 3.

In summary, the prototype CGIVS for the TORNADO training simulator showed deficiencies in the following areas: Scene content was inadequate for the training of en route flying, ground attack and final phase of air-to-air combat due to the limited number of edges per scene.

Resolution was inadequate for the training of en route flying, ground attack and final phase of air-to-air combat. The field of view was inadequate for the training of the final phase of air-to-air combat and ground attack due to the number of channels.

The visual system lacked realism because the CGIVS had no texturing and curved shading capability. All faces were presented in uniform colors.

As a result of the evaluation performed, the general characteristics of the CGIVS for the TORNADO training simulator were modified as follows:

1. Number of channels increased to three and expandable to five in order to increase field of view.

2. Real-time scene capacity increased to 8000 edges and 4000 point lights.

3. An unlimited on-line data base was provided by dynamic reloading.

4. View plane elements were increased to 875 lines with 1000 elements per line resolution.

5. Texturing and curved shading was added.

An important aspect of the entire program was the successful cooperation and working relationship established between industry, the German Air Force and the Navy.

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