MARS: A TARGET PROJECTION SYSTEM FOR AIR COMBAT SIMULATORS

Pierre Rapp
THOMSON-CSF Division Simulateurs
Osny, FRANCE

ABSTRACT

The operational experience and technical know how acquired in air combat simulation has led THOMSON-CSF Simulator Division to develop a new simulator projection system. This equipment called "MARS" for Multiple Aircraft Raid Simulation, provides combat pilots with better perception of their targets for multi aircraft training by overcoming the limitations of light valve projectors. In particular, the use of laser and acousto-optical techniques provides high contrast images without halo. The images displayed by MARS are usually ground or air targets, missiles in flight and the sun, but it is also possible to display gunnery effects such as tracers and countermeasure decoys.

INTRODUCTION

Simulation of an air combat visual environment in domes is currently obtained by superimposing on a low resolution background image of land and sky, brighter high resolution images of small objects such as airborne targets and missiles of various sorts which are important to the pilot.

The increasingly improved performance of modern combat aircraft has led THOMSON-CSF to develop the combined MARS-JANUS system to meet all the operational requirements for an air combat simulator for these aircraft, namely:

- full compliance with the pilot's field of view,
- improvement of the terrain/sky image, particularly at low altitudes,
- improvement of the resolution and quality of the projected targets
- reproduction of a multi-target environment.

The JANUS system, which is not the subject of this paper, meets the first two requirements by projecting a dynamic full field image giving the pilot speed, altitude and attitude visual cues.

The MARS system provides a decisive reply to users' insistent requests for improved target image resolution and quality. The outcome of an air combat in a complex multi-threat environment is very closely linked to the rapid and unambiguous identification of the target(s) and the exact evaluation of its behavior.

To achieve this, it is important that the image be bright with high contrast sharp edges which give a good indication of shapes, therefore of the type of aircraft, its armament and its instantaneous attitude.

Existing target projection systems use CRTs or light valve projectors whose low contrast and the presence of a halo around the target limit the quality of the target images by their insufficient contrast. To be perceived, the target images must be brighter than the terrain/sky background. The low contrast of existing projectors (75 to 100:1) gives rise to an objectionable halo around the target image especially when the image is projected against the darker parts of the terrain background. The halo effect increases with projector brilliance, degrading the content of the image itself and reducing the perception of detail in the image.

A good quality image is particularly required when the targets are at distances critical for combat i.e. when the result of the encounter depends on the rapid and reliable identification and evaluation of the targets by the pilot - namely between 1500 meters and 6000 meters.

The MARS target projector considerably improves the luminosity and sharpness of the image in this particular range of distances, thereby giving the pilot the vital target information he needs.

OPERATIONAL REQUIREMENTS

Pilots judge combat simulator target projectors essentially on their capacity to provide good perception of targets at long range. Experience in air combat has shown that there are three main domains:

- short range: targets closer than 1500 meters,
- medium range: targets between 1500 meters and 6000 meters,
- long range: targets beyond 6000 meters.

In the first two domains, pilots require to recognize:

- the type of aircraft and whether it is friendly or hostile,
- its weapons,
- any changes in its configuration such as reheat, airbrakes, variation in wing geometry, etc.

The medium range domain is the critical domain in air combat because it is here that the visual identification can be decisive. All other things being equal, it is the first pilot to see the other who stands the best chance of winning. "He who sees first lives longest". The best projected target quality must therefore be provided in this domain.

At long range, pilots have no special requirement other than an image showing the presence and position of the target. They certainly do not wish to have the detection of the target facilitated by the presence of a halo.

Note: the above considerations are clearly subject to fluctuation depending on weather conditions and the pilot's visual acuity under combat constraints (altitude, fatigue, workload).

Research undertaken by THOMSON-CSF with the cooperation of the CERMA (French Aerospace Medicine Study and Research Laboraroty Center) concerning the mechanism of recognition of small objects and the sensitivity of the human eye, showed that to meet the user's requirements, it was necessary to improve the contrast by removing the halo surrounding the target image (see figure 1) and to improve the brightness and resolution of small images.

These improvements are obtained by replacing the conventional light valve projector by a laser based MARS projector.

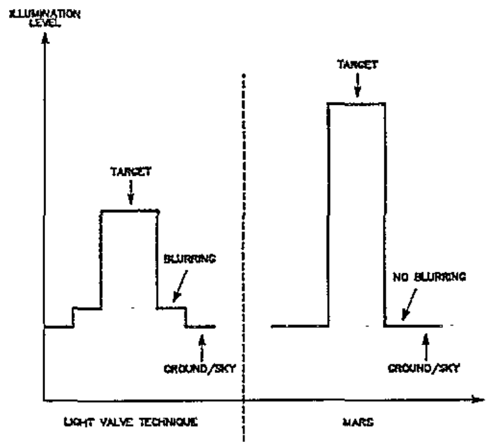

Figure 1

DESCRIPTION OF THE MARS PROJECTOR

The MARS projector consists of the following main subassemblies (Figure 3):

- the projection system itself comprising:
  - . a laser source,
  - . an energy distribution device,
  - . several independent projection heads.
- a dedicated computer system which computes the parameters and commands for the computed image generator (CIG), the video and servo modules.
- digital servo modules driving the projection heads.
- a video module linking the CIG to the projection head.

Projection system

The laser source emits a blue beam and a red beam. The combination of these two beams gives a white which the International Commission on Illumination has recommended for good visual comfort.

Each beam is divided into as many beams as there are projection heads, the light being conducted to the heads via optical fibers. This arrangement has the advantages of simplicity and flexibility and minimizes the space occupied by the system in the dome.

The projection heads consist of the following:

- a bichrome modulator (red and blue),
- an optical mixer combining the red and blue modulated beams,
- an optical attenuator for adjusting the luminosity for distance and gray out,
- an X-Y scanner which traces the image,
- an optical device performing the functions of image transport, zoom and focus.
- an azimuth and elevation deflector with motor driven mirrors.

Acousto-optical modulator assembly

. Principle (Figure 3)

The laser beam to be modulated traverses a lead molybdate crystal which is also traversed by an acoustic wave. The incident beam is transformed into a beam transmitted without modulation and a diffracted beam modulated by the acoustic wave. The diffracted beam contains about 90% of the incident energy. This efficiency is optimized by making the incident angle equal to Bragg's angle.

1 Incident beam
2 $PbMoO_4$ crystal
3 diffracted beam
4 piezo-electric transducer
5 modulating signal
6 transmitted beam

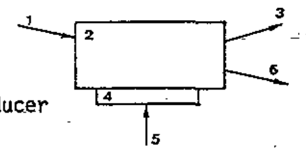

Figure 2

. Construction

Each bichrome projection channel has a modulator with two separate crystals (one for the red beam and one for the blue beam) giving the additional capability of providing a means of continuously varying the amount of blue or red in the composite beam (if required).

At the output of the modulator an optical mixer combines the beams. The resulting white beam is then sent to the scanner.

Scanner assembly

The X-Y scanner specially developed by THOMSON-CSF generates either a TV image or a calligraphic image from the modulated beam. The XY scanning signals are synchronized with the video signals driving the modulators.

Optical assembly

An optical assembly located between the scanner and the deflector provides the functions of image transport, image size (zoom) and focussing. The zoom and focus drive signals are computed in the MARS system computer. The size of the projected target is adjusted by an optical zoom for close distances and by an electronic zoom located in the CIG for distant targets. The optical zoom is selected to meet the customer's requirements for the range of target distances and to provide a resolution compatible with the separating power of military pilot's eyes which happens to be better than the average (1' of arc).

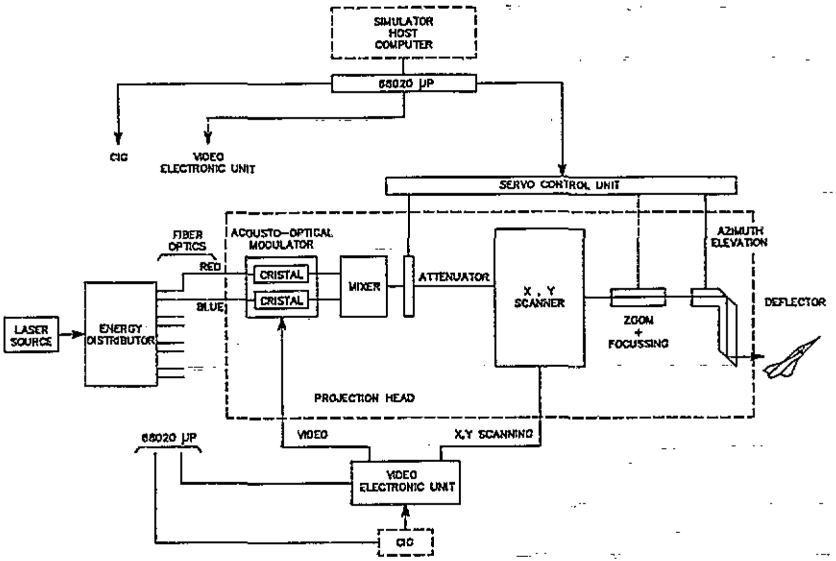

Figure 3 MARS GENERAL OUTLINE

Deflector

The miniaturized deflector is of conventional design and provides unlimited movement in azimuth and elevation.

Dedicated computer

The MARS projection heads are controlled by a microcomputer facility based on a MC68020 microprocessor and an MC68881 floating point coprocessor. The processors interface via a VME bus.

The software loaded in the computer includes support software, application software (operation of the projection heads and computation of rotational motion) and integration and maintenance software.

The computer interfaces with the following:
- the simulator host computer for target and fighter positions and attitudes,
- the image generator for transmission of parameters of the displayed targets,
- the servo modules for transmission of drive commands to the electro-mechanical devices.

Video module

The video module provides the following main functions:
- adaptation of the CIG image to the characteristics of the scanner
- generation of the video signals for the modulator,
- generation of the video synchronized scanning signals for the scanning modules.

Servo module

The following commands are sent to the projection heads:
- the positions of the azimuth and elevation deflector mirrors,
- the zoom lens focal length,
- focussing,
- attenuation.

The deflector azimuth and elevation mirrors are driven by torque motors and have unlimited rotation to allow projection to any part of the dome. Digital servo systems are used, providing better fidelity and maintenance flexibility. The feedback signals are also input to the computer to provide enhanced monitoring of the servo loops.

Safety

In addition to the usual safety precautions applied to laser installations, THOMSON-CSF has paid particular attention to the safety aspect, providing complete protection to all persons entering a simulator equipped with a MARS system. System operation depends not only on the correct operation of its subsystems (presence of scanning for example) but also on conditions related to the current phase of simulation. For example, in normal operation the projectors will not operate unless the pilot is in his seat with the canopy closed. This prevents the pilot from being exposed to direct rays from the projectors which are out of his normal field of view.

PERFORMANCES

Typical performance data given below illustrate the capacity of the MARS system to project high contrast, high resolution target images. The performances can be tailored to suit the user's specific requirements.

The following assumptions have been taken into account:
- diameter of dome: 8 meters,
- dimensions of the real target: 15 meters (e.g., *Mirage 2000*)
- pilot's eye at the center of the dome,
- optical zoom chosen to obtain resolution better than the human eye,
- screen gain: 0.9.

Projection head servo speed and accuracy are essential especially when it is necessary to switch the image from one head to another when the projection heads are located on each side of the cockpit. The small size of the heads gives minimum occultation.

static accuracy per axis:	better than 1 mrd,
max. angular velocity per axis:	20 rd/s,
max. angular acceleration per axis:	200rd/s^2,
separation between mirrors:	60mm,
mean swept diameter:	80mm.

A/C - target range (meters)	150	300	1200	6000
Zoom	1 <	2 optical	8.4 ><	electronic >
Definition in lines per image	256	constant	256	variable 51
Resolution in Min. of arc	1.7	0.85	0.2	constant 0.2
Luminosity lux ft L	>40 >4	>40 >4	>100 if necessary >10 if necessary	
Contrast			>500	

In addition to the high image quality the innovative design of the MARS system has two outstanding advantages:
- multi-target capability because of the advanced level of miniaturization of the projection heads,
- display of high light level special effects such as afterburners, missile firing flash, IR decoys, tracers, navigation lights using the calligraphic mode.

APPLICATION TO SIMULATORS IN DOMES

The unique features of the MARS system make it exceptionally suitable for use as a multiple target projector in air combat and gunnery simulator domes. The product was designed with sufficient flexibility to enable it to interface with existing installations such as connection to any host computer, adaptation to various simulator cockpits and use of specific CIG.

It is quite possible to arrange dynamic management of the projection heads so that the same head projects either a target or a missile, etc., depending on the tactical situation at the time and/or the direction in which the pilot is looking (area of interest).

An artist impression of a typical MARS/JANUS* installation in a dome is shown in Figure 4. The projection heads are arranged in pairs on the left and right of the cockpit. The switching of the image when the projected image passes from one side of the cockpit to the other is performed out of the HUD field of view.

* JANUS (from the two-faced Roman god) is a system developed by THOMSON-CSF which uses two fish-eye projectors to project a terrain/sky image on the front hemisphere and the rear hemisphere simultaneously. The two images provide the pilot with realistic cues of altitude changes, aircraft attitude and ground speed.

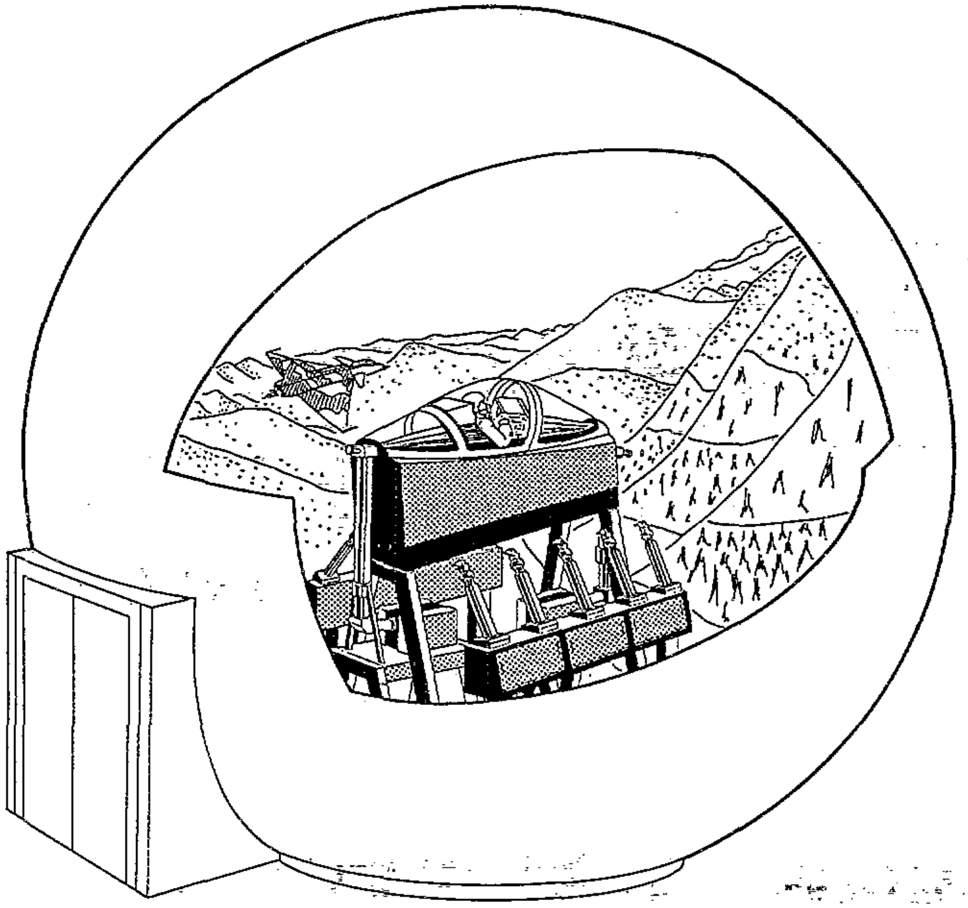

Figure 4

CONCLUSION

The main feature of the MARS system recently developed by THOMSON-CSF is its capacity to project targets having sufficient contrast and resolution to enable the pilot to identify and evaluate targets at medium and long ranges. The system's modularity gives it the capability of projecting a diversity of moving objects ranging from target aircraft to tracer bullets, thereby creating the multi-threat environment that future air combat simulators will require.

REFERENCE

Les fonctions de sensibilité aux contrastes de luminance polychrome chez l'homme (Study of human contrast sensitivity to polychrome luminance). Thèse Docteur MENU CERMA 5/12/1986.

ABOUT THE AUTHOR

Pierre Rapp is a project Manager in the fighter aircraft simulation department at THOMSON-CSF Simulator Division. He is currently involved in R & D coordination on air combat simulators. He has been working in the simulation field since 1969.