FULL LENGTH PAPER

VISUAL INSTRUMENTATION SCHEME FOR AIRBORNE STORES SEPARATION STUDIES

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Abstract

The most critical test in the certification of a new weapon on a tactical aircraft is the safe separation test performed to demonstrate that the weapon can be deployed safely and effectively. This differs from other missile releases because this is a manned mission (Aircraft Pilot is involved in the mission). These separation tests are performed at various Airspeeds, Mach No, Angle of Attack, Altitude, and normal acceleration over a defined operational envelope. After the basic simulation tests for finding the potential trouble spots, a deployment envelope for flight tests is made for acceptance. Earlier methods used to have normal airborne video cameras on the test aircraft and chase aircraft to record the separation event. The data was limited by the speed of the cameras (25fps) and provided only qualitative results. Quantitative data is essential to validate the new weapon system designs so that the data can be used to improve the weapon performance. Since weapon systems are becoming smaller, faster and more precise, the data requirements for adequate testing and evaluation have become more stringent. Monitoring the initial phase performance of the missile release from the aircraft requires the Visual Instrumentation that gauges how well the system has operated. Critical imaging and high speed optical data collection are required to extract accurate and precise measurement information. The performance indices are Time taken for the missile to clear the launcher, Velocity profile, Tip-Off after release from launcher, roll/yaw build-up after launch, effect of missile plume on aircraft etc. The above parameters aid in post flight analysis and debriefing mission. Predicted data values are compared with the captured data for design improvements. This paper presents the advanced and optimal Visual Instrumentation Scheme for deployment of digital high speed airborne video system and various constraints/considerations for airborne platforms for different launch configurations of Air-to-Air and Air-to-Ground Missiles. The limitations of implementation are the limited space availability, adverse operational conditions, ambient lighting, provision for real- time video transmission, and mounting problems. Successful deployment of such a scheme for capturing the release of Air- to- Ground Missile from Helicopter and the results obtained, analysis are featured.

Index Terms *: Visual Instrumentation, High Speed Imaging, Motion Analysis, Stores Separation, Field of View(FOV), fps frames per second, CCD-Charge Coupled Device, CMOS-Complementary Metal Oxide Semiconductor, COTS Commercial Off The Shelf*

Introduction

Because of the technical advances in CCD/CMOS Sensors, and declining cost of high speed cameras in recent years, applications based on high speed images have increased. Many new applications of the high speed imaging have been developed in the fields that include medicine, industry, sports and military. One of the most important applications in military is for Stores Separation Studies.

However the high speed images captured in airborne applications have high blur, low contrast, low brightness and high magnifications of release objects of interest. In addition, there is still an inherent limitation that affects the quality of high speed images and hinders their deployment: Low Shutter Speeds. This is caused by the diffraction effects induced by the high speed optical system which produces high blurred images due to faster object movements. The edge and texture information about objects in high speed imaging have to be more distinct for analysis. To capture high quality images for airborne applications where the camera mounts are susceptible to higher shocks and vibration levels, it is necessary to calculate all the effects for getting the best contrast video for analysis. In this paper we present an adaptive visual instrumentation scheme for capturing the missile release from an aircraft and a case study for missile release from helicopter.

Constraints Stores Separation

Before carrying out release/drop flights from aircraft, it is mandatory to check the integrity of the missile in captive condition. These tests are called Captive Flight Trials. These tests are planned in different phases to prove structural and mechanical integrity, avionics and electrical systems interfacing with aircraft/helicopter.

For ensuring the safe separation of an air-to-ground missile, compatibility flight testing is mandatory. The objective of such a flight trial is to demonstrate that the helicopter/aircraft can fire the intended missile safely and satisfactorily and achieve the required levels of maneuverability and performance for each missile.

The ballistic coefficients like missile drag, tip-off, initial launch velocity, roll rate are simulated for a safe stores separation. But these conditions vary under the influence of the aircrafts flow fields. For testing all these conditions a ballistic flight trial is conducted to prove that the missile release is safe with respect to the constraints like missile plume effect on aircraft/helicopter, flutter, missile loads, stability and control, vibration and shock, aero-acoustic, and thermal effects as discussed in [1].

Missile Plume Effect

Missile plume affecting the aircraft structure, sometimes air intake is the most critical aspect of stores separation. Exhaustive theoretical studies are carried out before any flight test from aircraft. Visual Instrumentation scheme will aid in assessing the plume affects on the aircraft structure and other adjacent missile/store.

Flutter

Aircraft wing flutter with the missile (stores) is a prime determinant of the flight release envelope. This can be analyzed through the accelerometers and strain gauges instrumented at critical locations on the aircraft and missiles.

Missile Loads

Missile loads play a crucial role if the aircraft is maneuvering at the time of stores release. This will have an impact on both the missile and aircraft. Visual Instrumentation should cater for capturing of Stores Separation/Release at these conditions.

Thermal Effects

Thermal testing validates the missile performance under actual thermal environment experienced during high temperature zones of flight. Temperature instrumentation is done at launcher, missile - internal, external and walls, and fuselage (aircraft). Analysis of this data validates the specifications and /or design limits.

Vibration and Shock

Missile experiences tremendous vibrations induced by own and aircraft/helicopter during the carriage. Also, missile release or drop will produce significant levels of shock and vibration to the aircraft. Aircraft and missile is instrumented to measure the vibrations and the data is analyzed for spectral density vis-à-vis design specifications.

Aero Acoustic

This determines missile withstanding capability to the aero acoustics generated by the aircraft. Sound pressure level are recorded and analyzed for any adverse effects on the missile.

For the missile design team, to prove the launch capabilities from aircrafts, it is necessary to capture the visual data along with instrumentation requirements for validation of design specifications.

Requirement

To carry out flight testing of variety of weapons (like air to air missile, air to ground missile, short range anti tank missile) from various airborne platforms (like aircraft, helicopter).

Visual Instrumentation Scheme

To meet the above requirements for capturing the missile release/drop, an efficient scheme is designed and presented here. This visual instrumentation scheme is adaptive to various stringent deployment conditions to cater the following:

- Capture the missile release/drop event from the launcher
- Pitch, roll and yaw rates during release/drop
- Missile separation timing from the aircraft
- Plume details from the nozzle exit and its effect on the aircraft/helicopter
- Initial velocity measurement of the missile
- Capture the autopilot operation
- Snapshots of the missile release from the aircraft
- Safety surveillance for the aircraft

The scheme is broadly divided in to three categories:

- Onboard camera plan
- Ground camera plan
- Chase aircraft camera plan

The constraints to be taken care for deployment are:

Shutter Speeds : The events of missile release/drop happen in very small interval time. Due to relative motion of the missile with respect to the camera, the captured images are blurred if shutter speeds are low. Higher shutter speeds are to be programmed for blurred-free images. The trade-off between the lighting availability and shutter speeds is to be properly taken care for good contrast images.

Lighting Conditions :Missile release is planned at various altitudes where lighting conditions are unknown. To ensure good quality images, proper lighting conditions are to be envisaged. Reflections from aircraft, missile plume etc will have significant impact on the image quality. Another important criterion called "Blooming" is to be addressed for preventing image saturation.

Triggering : Due to the smaller memory sizes, the high speed cameras trigger is to be programmed accurately for precise event capturing. Onboard triggering scheme should be integrated with missile release processor. The memory should be made available if multiple launches are planned.

Mounting of the Camera(s) : The mounting of camera should be capable of the environmental conditions of carriage. It should have the pan and tilt adjustments to meet the requirements.

Live Transmission : For the mission controller to take decisions during launch operations, it is mandatory to transmit the video data in real time to the ground station. This also serves as the backup source of data in case of any catastrophe.

Power Supply and Triggering Scheme : The scheme should address power supply requirements of camera/transmitter, switching ON/OFF scheme, triggering of camera at appropriate time, compatibility with the aircraft power supply.

Onboard Camera Plan

This plan is made by considering different airborne platforms like Su-30 MKI, Mirage 2000, LCA, MiG29, and ALH.

Near Field Photography : Near field photography is intended for capturing the minute details of missile release/drop within the close vicinity. This data is used in time measurements, plume effect on aircraft structure, tip off from launcher, and roll rate measurement. The lens selection and the number of cameras required are based on the station separation distance, length of the missile.

Three camera plan worked out for an air-to-air missile on Su30MKI is shown in Fig.1. 8mm lens with f1.8 have been chosen.

It is also essential to record the missile travel towards the nose of the aircraft to see the effect on the aircraft nose. To capture this, another camera looking towards the nose is also planned. These three high speed cameras will suffice to capture the missile events in near field.

Far Field Photography : Far field photography is intended for capturing the missile release/drop up to a distance of few km from the aircraft. To cater this, lipstick camera with 3.6mm lens is planned on the vertical fin tips. The location of camera and lens are so chosen that it will cover the missile at farthest station and nose tip simultaneously. Location of the camera shown in Fig.2

Field of View (FOV) of camera in horizontal and vertical planes are shown in Figs.3 and 4.

Ground Camera Plan

Ground camera plan is to capture the missile release from ground at sufficiently larger distances from the trial point. Thermal camera has been planned for this purpose to track mother aircraft, capture missile release, and damage assessment to the target aircraft.

Chase Aircraft Camera Plan

This is required to capture the missile release/drop event from the chase aircraft. This serves as the primary source of information in case of catastrophe. Since the chase aircraft is located at a safer distance from the missile release aircraft, lens has been chosen accordingly. The other factors considered are the weight of the camera (for handling by the navigation pilot), view finder (for getting the camera view), power supply (battery operation throughout the mission), onboard storage, higher frame rate operation (desirable). Background lighting, shutter speed adjustments are to be taken care for obtaining good quality image for analysis.

Deployment Scheme for Air-to-Ground Missile Release

Introduction

This Scheme is implemented to capture an Anti-Tank Guided Missile (ATGM) missile launch from Helicopter. During the Ballistic flight trial, the requirement was to capture the missile release from Helicopter, which is fitted on the armament boom. The boom is mounted on the floor board of helicopter by clamps and it extends out on either side of the fuselage passing through side panels (Fig.5).

The front view showing eight missile configuration is presented in Fig.6.

The main mission objective was to prove the safe missile separation and ensure safety of Helicopter and pilots. The Visual Instrumentation for this trial is planned as following:

- On-Board Camera Plan
- Ground Camera Plan

Since the missile was planned to be launched from Helicopter at 50m, Chase Helicopter camera was not deployed.

On-Board Camera Plan

Two flight-qualified Video Cameras with housing are planned on-board. One Digital High Speed Video Camera capable of recording 500 fps at 1280 x 1024 pixels, and one normal video camera which at 25fps at 720 x 576 pixels resolution. Camera memory is programmed with multi-buffer option and the trigger signal comes from the missile fire command. Locations of these cameras are shown in Fig.7.

The essential purpose of these on-board cameras was to capture the launch for measuring the critical parameters like missile roll rate, missile plume effect on fuselage, initial velocity, and separation timing.

Ground Camera Plan

The Ground Camera coverage plan was made with Two Digital High Speed Video Cameras, One normal video camera, and one Digital Still Camera at 7 frames/sec. This plan will validate the parameters measured from on-board camera data and predicted data from simulation.

Calculation Method : The angles from the camera's lens focal point to atleast two points on the released missile are measured/estimated through their derivation from frame center. The Fig.8 and 9 depicts the exercise with typical parameters. The distance to these two points from the focal point is estimated by sizing the object (missile) image in the frame. This information is used to calculate the positions of the two points in space and thus the spatial angles and trajectory of the missile.

Hardware Selection : The main effort in hardware selection has always been focused on finding COTS hardware suitable for the application. All the constraints like lighting, triggering, spatial resolution, exposure, mounting, blooming etc. were taken care in deployment for the scheme.

Lighting Requirements were taken care by calculating the light availability with formula:

Foot candles required = (25 * f-stop^2)/ISO * exposure time

Candle power required = Distance^2 * foot candles (1 Foot-candle = 10.76391 Lux.)

Results

The results obtained from the above Visual Instrumentation Scheme are presented here. These include Timing, Flame lengths, missile roll, and initial velocity. Fig.10 shows while the trial was on.

The obtained results are compared with the simulated and predicted data and found satisfactory.

Merits

The merits of such a scheme are its ability to provide visual data along with engineering data for Missile Stores Separation Studies. It also provides a base for trajectory reconstruction from visual data from high speed cameras. Other merits include:

- High Quality Video Image Capture
- Reduced work load and turn- around time between sorties
- Insensitive to lighting constraints
- Adaptable to multiple platforms and missile configurations
- Does not require adjustment for store size or location
- Improved reliability

Acknowledgements

We thank the Project Director, ASTRA and Technology Director, Instrumentation, Defence Research and Development Laboratory, Hyderabad, India for providing valuable guidance and support for the work rendered.

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Fig.1 Two High Speed Cameras Looking Towards Outer Station on Su 30MK1

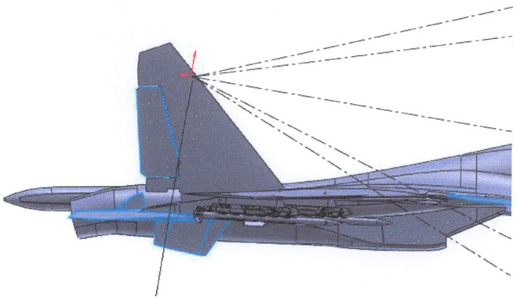

Fig.2 Location of Lip-stick Camera on SU 30 MK1

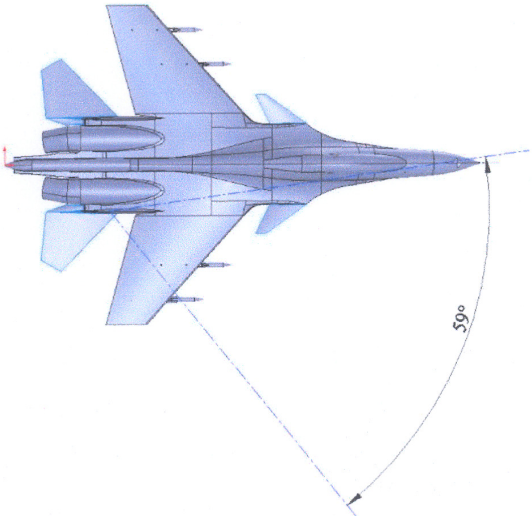

Fig.3 FOV of Lip-stick Camera in Horizontal Plane

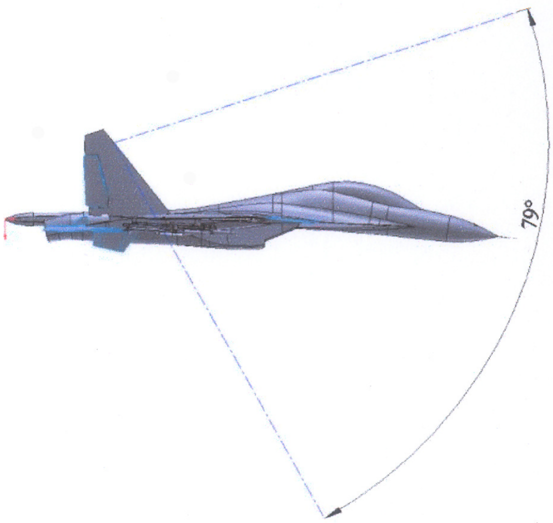

Fig.4 FOV of Lip-stick Camera in Vertical Plane

Fig.5 Helicopter Carrying Missiles

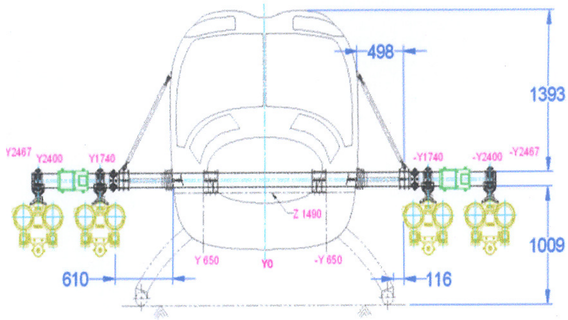

Fig.6 Front View Schematic of Helicopter

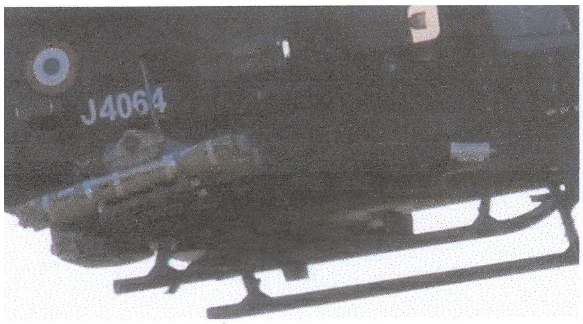

Fig.7 Location of On-board Cameras on Helicopter

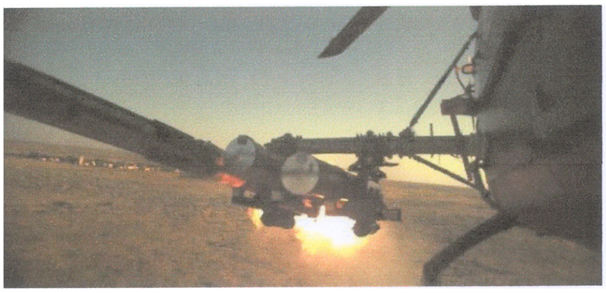

Fig.8 Launch Tube Time : 200 m sec

Fig.9 Missile Roll Angle
T = 242.67 m sec; Roll Angle : 45 deg

Fig.10 Missile Flame Lengths