Chapter 1 – INTRODUCTION

1.1 BACKGROUND

Technological developments in the realm of optronics have led to innovative concepts in the mission management of current and next generation ground attack aircraft. Particularly, tactical systems including Laser Range Finders (LRFs), Laser Radars (LADARs) and Laser Target Designators (LTDs) are used today by most military forces in the world and new promising laser technologies are being explored. Most laser systems are active devices that operate in a manner very similar to microwave radars but at much higher frequencies (e.g., LADAR and LRF). Other devices (e.g., LTD and beam-rider) are used to precisely direct Laser Guided Weapons (LGWs) against ground targets. A combination of both functions is often encountered in modern integrated airborne navigation-attack systems. Compared to similar microwave devices, the higher frequency of laser systems has the beneficial effect of smaller components and remarkable angular resolution values. On the other hand, laser systems performance are much more sensitive to the vagaries of the atmosphere and are thus generally restricted to shorter ranges than microwave systems.

For the accomplishment of aircraft operational tasks with LDT/LGW systems, it is important to optimise flight profiles in both self-designation and co-operative attack missions, allowing stand-off operations and safe escape manoeuvres. This can be achieved by a careful mission planning (i.e., modelling and simulation), taking into account all elements playing a significant role. These elements obviously include weather conditions (i.e., laser beam atmospheric propagation), target characteristics (e.g., reflectance, shape, dimensions), and aircraft-target relative geometry during the attack (i.e., LTD/LGW tactics).

Similarly, for flight experimental and training activities with laser systems and LGWs it is important to take into account the tactics of employment of the systems/weapons in different operational scenarios and to verify their performances in realistic operational and environmental conditions at the ranges. Also important for test/training purposes is the definition of laser safety criteria, since most systems currently in service operate in the near infrared with considerable risk for the naked human eye.

Eye-safe technology is also being applied to airborne laser systems. Promising applications that are now receiving a growing attention include LADAR systems for obstacle warning in low-level flight missions. These systems are particularly attractive for helicopter applications. Essential steps in the development of such systems are obviously laser beam propagation analysis in various weather conditions, definition of the obstacle detection performances and implementation of suitable obstacle classification and prioritisation algorithms.

Since the beginning of the 90's, the Italian Air Force Official Flight Test Centre (RSV) has conducted various test programs with LGWs, and LTD/LRF systems for both airborne and ground applications. In some cases, the activities had to be carried out in foreign test ranges, equipped with ground instrumentation sufficient for some measurement tasks (e.g., determination of laser systems pointing accuracy), but not fulfilling the RSV test requirements. Particularly, in many cases, laser spot data gathering and post-mission data analysis were very limited, considerably reducing the scope of the experimental activities and often increasing the time and money required to complete the flight test campaigns. Furthermore, once the various laser systems were introduced into service, there was a growing need for an effective training at the ranges, with adequate real-time data acquisition and post-mission data analysis tools.

Therefore, between 1997 and 1998 the Italian Air Force set the requirements for upgrading the PISQ test/ training range (Poligono Interforze del Salto di Quirra – Sardinia – Italy), adding new facilities for carrying out safe training and experimental activities with airborne and ground laser systems, together with LGW delivery tests.

According to the initial requirements, the PILASTER (PISQ LASer Test and Evaluation Range) research and development program was divided in two different phases. The aim of the first phase of the program (1999 – 2002) was to provide an initial operational capability for carrying out, in fully safe conditions, ground tests and flight experimental activities (with related measurements and semi-automated data analysis), required for performance evaluation of military laser systems. The successive phase of the program (2003 – 2006) was aimed to implementing the PILASTER full operational capability, required for performing all laser test/training activities, including all mission planning and fully-automated post-mission data analysis tasks.

1.2 AIM OF THE AGARDOGRAPH

The objective of this AGARDograph is to identify methods for evaluating the performance of laser systems operating in the infrared (including flight test, modelling and simulation), with different operational and environmental conditions. Present laser technology status and future technology trends are investigated, in order to determine the relative strengths and weaknesses of the most promising laser technologies when applied to airborne systems. Suitable mathematical models for laser beam propagation, geometric analysis, target reflectivity and detection are identified. Safety issues are deeply analysed in the light of the operational requirements for airborne systems (including guided weapons), and the optimal design characteristics of range instrumentation for current and likely future laser systems test/training operations are identified. Finally, the requirements for tactical and test/training mission planning are defined, together with the kernel algorithms of suitable simulation programs capable to assist aircrews and flight test engineers in the determination of optimal aircraft flight profiles for operations at the ranges.

The Italian Air Force case study, linking most of the technical and operational issues discussed in this AGARDograph to the PILASTER development program, describes the research work performed for designing, developing and testing the PILASTER laser range for the Italian Air Force. This includes the design of new range instrumentation and facilities, development of innovative methods for military systems performance prediction/evaluation, determination of eye-safety requirements for employment of ground and airborne laser systems at the PILASTER range both during experimental and training activities, and extensive laboratory, ground and flight test activities performed by the Italian Air Force with state-of-the-art ground/airborne laser systems and weapons.

The following paragraph gives an outline of the format of this AGARDograph.

1.3 OUTLINE OF THE AGARDOGRAPH

The Chapter 2 of this AGARDograph describes some of the most important airborne laser systems and gives an overview of the main applications encountered in the operational field (some fundamental concepts are expanded in Annex A). Particularly, Chapter 2 reviews current laser technology status and future technology trends, with particular emphasis for systems now in service or under development in the NATO countries. These include the Italian Air Force LTD/LRF systems, various types of LGWs and LADAR systems both for helicopter and fixed-wing aircraft applications.

Chapter 3 discusses the key elements of laser systems performance analysis, with the aim of introducing the mathematical models required for operational mission planning and simulation. Particularly, suitable forms of the laser range equation are developed, for determining the performance of ground and airborne laser systems under specific conditions and with various types of targets. Furthermore, an outline is presented of the laser beam atmospheric propagation models used for PILASTER test/training operations (i.e., mission planning, safety studies and performance analysis) with ground/airborne laser systems. Finally, Chapter 3 discusses target reflection properties, and presents the operational considerations necessary for laser systems performance analysis (target/spot size, system error sources and effects,

mission geometry, etc.). A more detailed discussion about laser systems range and detection performances is presented in Annex B.

The PILASTER test/training range requirements are described in Chapter 4. Particularly, the laser range concept of operation is illustrated, and the general systems requirements set in 1998 for the PILASTER program are presented. These include requirements for both training and experimental activities, with a conceptual definition of the systems necessary both in the range operational area (targets, sensors, area-networks, etc.), and in the remote control-room.

Detailed information about the PILASTER design and technical characteristics, progressively refined during the various implementation phases of the program, are presented in Chapter 5. Particularly, the PILASTER Sensor Tracking and Measurement Unit (STU) and remote Monitoring and Control Station Unit (MSU) systems design is presented. The PILASTER STU system allows accurate measurement on the ground (i.e., targets locations) of various important laser parameters (beam pointing accuracy, energy received at the target location, spot geometry on the target, etc.). These information are recorded at the STU and passed, through the range local and wireless area networks (LAN/WAN) to the MSU placed in the remote control-room. All information required for real-time mission management (i.e., eye-safety verification and test/training operations) are then displayed and recorded, in suitable formats, at the PILASTER MSU.

The methods developed for evaluating the hazards associated with the use of ground and airborne laser systems, are presented in Chapter 6. Particularly, safety issues of state-of-the-art Nd:YAG target designators are thoroughly investigated, in order to identify operational procedures and limitations for the employment of such equipment at the PILASTER range during execution of both test and training missions. Various mathematical algorithms are presented, developed for the PILASTER simulation and mission planning tools, which allow a complete verification of laser-safety for ground and airborne laser systems.

In order to optimise the employment of the systems in service (e.g., LTDs and LGWs), as well as for developing the new PILASTER systems, and fully defining test/training operational and technical requirements, it was essential to perform a number of experiments. Some of these experiments, such as determination of LGW seeker detection thresholds, PILASTER sensors selection/calibration and measurements of target materials reflection properties, were conveniently performed in a laboratory facility. Other important measurements and tests were performed during appropriate field and flight test sessions.

Chapter 7 describes the laboratory experimental activities carried out during this research. These include:

- Determination of LGW Seekers Detection Thresholds;
- Measurements of Surface/Paints Reflection Properties (PILASTER targets);
- PILASTER Sensors Testing and Calibration;
- LOAS[1] Laser Sub-system Testing; and
- Test of Laser Protection Filters (Cinetheodolites, Ground Personnel and Aircrew).

Particularly, the specific test aims, test methods (instrumentation requirements, details of measures performed, etc.) and test results, are presented in this chapter.

[1] To improve clarity, the technical abbreviation LOAS (Laser Obstacle Avoidance System) is used in this volume, instead of LOAM (Laser Obstacle Avoidance Marconi), which is the commercial name of the product developed by the Italian company Marconi-Selenia (now Selex-Communications).

Ground experiments performed during this research are described in Chapter 8. These include NIR laser beam atmospheric propagation measurements, LTD/LRF pointing accuracy tests, systems harmonisation and performance evaluation trials of the STU components of the PILASTER system. Furthermore, dedicated ground trials were performed on the LOAS system in order to assess its detection performance (in various weather conditions), and to verify the reliability of its obstacle classification algorithms. The various test objectives and procedures, instrumentation employed and methods of analysis are described in Chapter 8, together with results of the ground experimental activities.

Chapter 9 describes the flight test activities performed during this research and gives indications about further activities planned for the future. Flight test activities performed as part of the PILASTER development project, included the following:

- Propagation Measurements in Oblique Air-to-ground Paths;
- CLDP Pointing Accuracy Measurements (TORNADO-IDS);
- CLDP FLIR Systems Flight Testing (TORNADO-IDS);
- LOAS Preliminary Flight Trials on the NH-300 Helicopter; and
- LOAS Flight Trials on the AB-212 Helicopter.

Particularly, the PILASTER STU and MSU systems were tested during their employment in real air-to-ground missions (both with and without deliveries of guided weapons). With the PILASTER systems in their operational configuration, atmospheric extinction measurements were performed with typical air-to-ground mission geometries (i.e., oblique laser paths), and the correction factors for the ESLM sea-level atmospheric propagation models were determined in these conditions. CLDP pointing accuracy (from geometric and energy spot measurements) was also determined during the TORNADO-IDS flight test campaign and CLDP FLIR systems tests were performed with various aircraft-target geometries.

The DGPS test activities were performed with the aim of selecting a suitable Position Reference System for both experimental and training activities (i.e., real-time and post-flight mission trajectory data analysis). Furthermore, the aircraft envelope limitations associated with the use of airborne GPS systems were determined.

The LOAS flight test activities were carried out in order to verify the functionality of the system in a representative operational environment (i.e., system detection performance in various weather conditions and with various obstacle scenarios), and to assess the efficiency of the LOAS obstacle classification/ prioritisation algorithms.

Chapter 10 is dedicated to the simulation tools developed during the PILASTER program for systems eye-safety and performance analysis. The mathematical models developed during the research were incorporated in the PILASTER simulation tools, allowing definition of test/training mission constraints and operational feasibility, together with post-mission data analysis. The assumptions adopted for implementation of the various algorithms in the PILASTER simulation/analysis programs are presented in this chapter, together with results of some relevant simulation tasks performed.

Finally, Chapter 11 summarises the main achievements of the PILASTER program and outlines suggestions for further work.