TITLE: Laser Designation Pod on the Italian Air Force AM-X Aircraft: A Prototype Integration

Laser Designation Pod on the Italian Air Force AM-X Aircraft: a Prototype Integration

Maj. Paolo DONZELLI, and Lt. (R) Roberto MAROZZA
Italian Air Force
Comando Logistico
Centro Sperimentale Volo
Reparto Sperimentale Volo – Gruppo Gestione Software
Aeroporto "Mario De BERNARDI"
Pratica di Mare, Pomezia (Roma), 00040, Italy
Tel: +39-06-91292003
E-mail: pa0189@panservice.it,rmaro@iol.it

Summary

The paper describes the prototype integration, on the Italian Air Force AM-X aircraft, of the Thomson Convertible Laser Designation Pod. The integration was conducted within the Italian Air Force Official Test Centre, and the process adopted was devised to produce a quick, low-cost, and low-risk sub-system integration. Software had the greatest part in the project, and software-engineering methods have been used to support the effort.
This integration is a good example of how a careful use of existing assets and experiences, together with the application of advanced software engineering techniques, can improve the effectiveness of an aircraft, keeping it up with the evolving needs. The integration is now being used as baseline by the aircraft manufacturer, thus reducing costs and times for the Italian Air Force.

Introduction

It is widely accepted that the key point in keeping up-to-date modern combat aircraft is no longer the airframe but the mission system. The airframes have a life that easily exceeds twenty years, while the mission systems rapidly become obsolete with respect to the ever-advancing state-of-the-art of the electronics and computers (Figure 1). The "mid-life update" is an already well-established term indicating a set of upgrades ranging from structural life extension to new radar, communication systems, navigation sensors, cockpit instruments, weapons. They are extensive and expensive processes, whose aim is twofold: substantial savings with respect to new designs (also due to simpler procurement processes), and aircraft with new or greatly enhanced capabilities. However, the availability of standard-interfaced, off-the-shelves sensors and the need of answering to the evolution of threats and tasks, pose the air forces with the problem to modify the mission systems more frequently. In addition, the key role played by the software in nowadays airborne systems offers new opportunities to execute upgrades of the combat aircraft without having large industrial facilities like those requested to modify or upgrade the airframes.

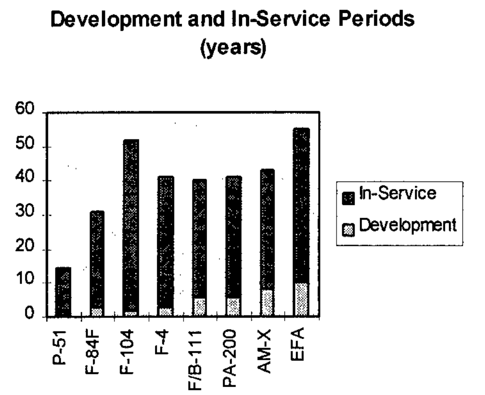

Figure 1 - Examples of aircraft operational life

As final users, the air forces are the best candidate to identify and analyse the new requirements to be implemented. Many of them have therefore developed in-house capability to study or to modify the software running on their aircraft. The Italian Air Force (IAF) is currently introducing into service the

Paper presented at the RTO SCI Symposium on "Aircraft Update Programmes. The Economical Alternative?", held in Ankara, Turkey, 26-28 April 1999 and published in RTO MP-44.

final version of its AM-X light attack aircraft. In order to improve its capabilities, IAF considered various retrofits to the mission system, and, specifically, the integration of a laser designation pod, to provide the aircraft with a laser guided bomb self designation capability.

We describe the software aspects of the integration, by focusing mainly on the requirements engineering activities. The hardware modifications were in fact limited to those strictly needed to connect the laser pod to the AM-X avionics system RIG (i.e., power lines, data cables, and control switches).
In the early stage of the requirements engineering activities, aspects such as the final system goals, the feasible alternatives, the different and often clashing interests of the various people affected by the system (pilots, developers, etc.) are addressed. The objective of the late phase requirements engineering activities is to produce a requirement document that would specify and constrain the final system, therefore suitable to be adopted in a contractual setting. We used a *rapid prototyping technique*, by exploiting an evolutionary prototype to elicit and validate system requirements. The analysis and the validation of the requirements drove the evolution of the project into an *incremental method*, where the use of the prototype caused a continuous evolution of the requirements themselves. We dedicated great attention to the requirements capture and validation, by carefully assessing their relevance both for the operative situations and for the implementation. As final result, the prototype has become an "animated" and "validated" requirements document, yet a fundamental component of the final system.

The following part of the present paper is organised as follows. Section 2 briefly introduces the integration problem. Section 3 provides an overview of the proposed solution approach, and of its rationale Section 4 discusses the project results, by providing both qualitative and quantitative insights. Finally, Section 5 concludes the description of the work, by summarising the benefits of the adopted approach.

Integration Problem Overview

The Aircraft. The AM-X has been developed by an Italian-Brazilian joint effort to provide both air forces with an aircraft capable to deliver a medium load out of short or semi-prepared airfield, at a moderate distance and high subsonic speed. Design studies began in 1977, and IAF took delivery of its first AM-X in October 1989. The basic AM-X performance and weapons data are published in [1]; only some of them have been reported in Table 1.

Manufacturer	Alenia (Italy) Aermacchi (Italy) Embraer (Brasil)
Wing Span	9.9 mt
Length	13 mt
Height	4.5 mt
Wing Surface	21 mt2
Engine	Turbofan (without a/b)
Max. Speed	subsonic
Max. Height	> 12000 mt
Max. Range (ferry)	> 3000 Km

Table 1 – AM-X Performance Data

The AM-X mission system is a typical first generation 1553-bus (Mil-bus) design, built around a digital mission computer, which acts also as bus controller (Bus Controller/Main Computer - BC/MC). The mission subsystems and sensors are connected as remote terminals.

The Man-Machine Interface (MMI) of the mission system is designed around two main displays: a "Multifunctional Head Down Display" (HDD), with configurable function keys, and a "Head Up Display" (HUD). The HDD performs also part of the route and display computations, thus leaving more computational power available on the BC/MC.

The Laser Designation Pod. The laser designation pod selected for the AM-X is the Thomson Convertible Laser Designation Pod (CLDP) [2], already operative on the IAF TORNADO IDS, on the French Air Force JAGUAR and MIRAGE 2000.

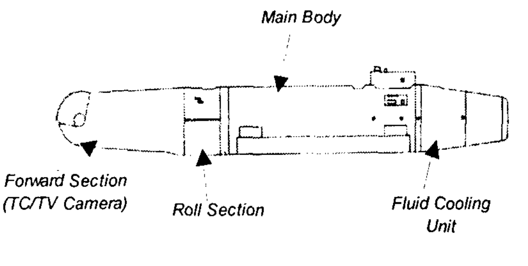

Figure 2 – The Convertible Laser Designation Pod (CLDP)

The CLDP (Figure 2) allows the aircraft crew to:

- visually acquire an on-ground target (the CLDP can be equipped with either a TV or Thermal camera, i.e. the Convertible capability);
- track the target (various internal algorithms are available);
- measure the target/aircraft distance;
- illuminate the target for subsequent weapon guidance.

Integrate the CLDP onto the AM-X. Despite the wide diffusion of similar systems, the integration of the CLDP on the AM-X posed upon us a new challenge.

The initial pre-feasibility study [3] (that prompted the acquisition of a prototype CLPD for the AM-X) had only defined the guidelines for the integration: the CLDP had to be used as a targeting sensor for the precision delivery of Laser Guided Bombs (LGB), and as a navigation sensor. The CLDP prototype integration project was therefore set off as a low-budget short-term activity aiming at (1) fully investigating the feasibility of equipping the AM-X with the CLDP, and (2) identifying an economical and low-risk integration solution. This kind of activities shows grey (or black) areas that generate risks for the project. Some risks are typical of the integration projects, some other are particular of this specific case, as discussed in the following.

Complexity of the solution space.
Finding a solution to the integration problem means to define a complete and consistent set of requirements that the new system (i.e. the aircraft equipped with the CLDP) has to satisfy. Only a minor set of these requirements concern technical (functional) aspects of the integration (e.g. the data the CLDP has to provide as navigation sensor); most of them are related to non-functional aspects. These regards both human factors, such as pilot workload, pilot performance, and situation awareness, and system quality attributes, such as safety, reliability, time and cost. In comparison with functional requirements, *non-functional requirements* are highly subjective (e.g. test pilots and front line pilots can have a different perception of the same problem), strictly related to the particular context, and more difficult to be discovered, stated and validated, without "interacting" with the final system. This increases the complexity of the solution space, introduces a certain degree of instability in the requirements, and makes difficult to compare different alternatives. However, being mistakes made at the requirements definition stage extremely difficult (and expensive) to recover during the subsequent system development, it is crucial, for the requirements engineering process, to be able to cope with such difficulties.

Complexity of the target platform
Although the AM-X mission system can be classified as a traditional one, it presents some elements of complexity. With regards to the stored data and to the functions offered to the pilot, it can in fact be defined as a distributed system. In other words, many of the functions in the mission system are performed via a co-operation of two or more subsystems. As a consequence, modifying or enhancing such functions requires operating on different equipment, which may adopt different hardware and software solutions (e.g. the used programming languages go from assembly, to Fortran, to Ada), requiring a broad range of skills not usually available in the same personnel. Moreover, equipment are often produced and maintained by different companies, so that the Air Force is faced with different levels of visibility, procurement processes and schedules.

Novelties of the Project
The basics of the Laser Guided Bombs operations were well known, thanks to the Tornado experience; but IAF specialists had still a limited inside knowledge of the AM-X mission system. In addition, it was the first example within the IAF of use of the CLDP on a single-seater aircraft.

Project Organisation

In order to reduce the associate risks, and to be compliant, at the same time, with the low-budget and short-term constraints posed on the project, it has been organised following some simple guidelines, that is:

- minimise modifications to the AM-X avionics system;
- exploit internal IAF resources and capabilities, i.e. personnel (test pilots and engineers, technicians) and equipment (low-cost avionics simulators and computers).
- re-use of previous experiences, both in terms of lesson learned and products. In particular, various projects regarding both the Tornado (among which the CLDP

integration), and the Italian Navy EH-101 helicopter[1] mission systems were carefully analysed, to identify requirements, algorithms, and software suitable to be reused and errors to be avoided.

In practical terms, this has led us to make precise choices regarding the *product* to develop, the *process* to apply, and the *team* to employ.

The Product. The integration of the CLDP to the AM-X avionics system asked both for new software and hardware. The new hardware was maintained to the absolute minimum: the on/off and laser safe/armed switches, the Mil-bus and the electrical signal/power lines. These new links were dictated by the CLDP, that was an off-the-shelves item.

We had more freedom for the design of the software architecture and for the allocation of the corresponding components onto the various computers of the avionics system.

We decided to concentrate in the HDD the software to control the CLDP, to minimise the number of equipment to be updated and to exploit the characteristics of the HDD itself. The HDD was in fact the newest equipment of the mission system, its Motorola processor provided the needed growth capability, and its software was written in Ada, the most advanced among the programming languages used on the aircraft. In addition, the HDD was ready to receive and display the images generated by the CLDP.

The software modifications to the BC/MC were instead limited to those strictly necessary to introduce some Mil-bus messages and to extend the navigation and attack functions, to employ the CLDP. For example, by enabling the BC/MC software to receive and use also data incoming from the CLDP, the correction of the position of the aircraft (i.e. present position fixing) can now be performed also using the CLDP (more versatile than the forward-looking radar or the simple on-top method). The new Mil-bus messages have been added to allow the CLDP to exchange data with the HDD. The BC/MC does not in fact perform any kind of control on the CLDP, but redirects the CLDP data to/from the HDD, and provides the HDD with basic data about the mission system (navigation, attack), and the aircraft (attitude, position, speed).

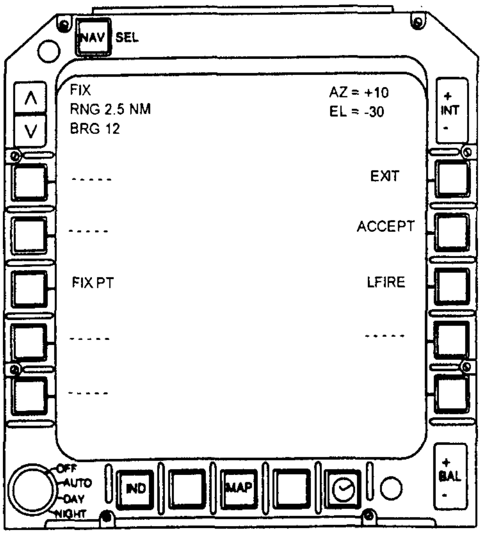

Figure 3 – Example HDD page for the CLDP

The HDD software has received only extensions. In particular: to handle the new Mil-bus messages [4]; to implement the required CLDP command and real-time control loop; to manage the CLDP pilot interface. The HDD software implements the pilot interface as a collection of cross-linked menu pages. By navigating through these pages, the pilot can access the various operations available: for example, synthetic maps, status of the equipment, and so on. For our purpose, the software has been extended to add some dedicated pages to control the CLDP. In other words, a new menu page has been devised for each main class of CLDP functionality. Specifically, it has been added a dedicated page to access/perform the various navigation operations (present position fixing, on-ground point acquisition), attack operations, testing operations, and so on. As example, in Figure 3 it is depicted in a simplified way the HDD page through which the pilot can perform a "present position fixing" employing the CLDP. By using this page, the pilot can select the fix point (FIXPT key on Figure 3), disable/enable the firing of the laser (LFIRE), read the position correction values (as range and bearing), and ACCEPT or EXIT the procedure. The Ada software architecture has been designed to obtain a high independence between the functions written to control the CLDP, and the functions implementing the interface. This allowed us to

[1] The EH-101, produced by UK WESTLAND and IT AGUSTA is a joint effort to produce a versatile multi-role platform for tactical transport, Anti-Submarine Warfare, Search And Rescue, and civilian transport.

produce stable software for the command and control, yet having the possibility to change the interface without impacting onto the deep (and more delicate) algorithms of the CLDP control. Whereas the definition of the final interface structure was obtained by continuously refining it with the pilot, the internal management of the CLDP and the used algorithms were an exclusive subject of discussion of the engineers. They worked using the Tornado experience and evolved them with a lower number of refinement cycles.

To conclude, in Figure 4 a simplified view of the chosen integration architecture is pictured. Here it is shown also the CLDP hardware control panel which provides, for example, the on/off and laser safe/armed switches.

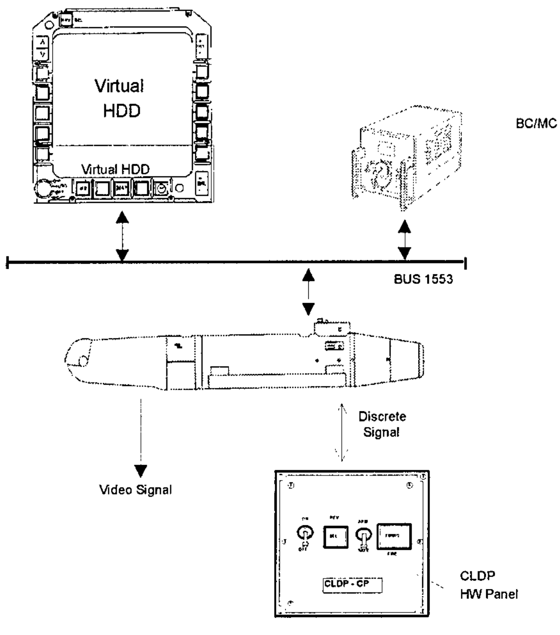

Figure 4 – Simplified view of the integration architecture

The Project Team. The project Team was organised in order to reduce as much as possible the number of involved people (and the corresponding co-ordination problems), and to exploit the available skills. Then, to increment the degree of concurrency between the different tasks to be performed, the project team has been divided up into 3 different sub-groups, with specific competencies, responsibilities and workload:

Software Development Team, with the task of managing the whole project and develop the necessary software, composed of 2 software engineers and 2 technicians. In particular, the group members worked together for the requirements, while each of them was dedicated to the single aspects of the ADA code, the Fortran code, the Assembler code and the operating systems.

Hardware Support Team, with the task of performing the CLDP hardware integration onto the AM-X avionics system and taking care of its maintenance, composed of 2 technicians;

User Group, with the task of collaborating the requirements elicitation and validation phases, composed of a test pilot and a Tornado test navigator. Both of them had specific experience with LGB operations, and were supported by front line pilots.

The Development Process. Two paradigms usually adopted within software engineering to reduce and manage risks associated with requirements instability and complexity have been adopted and customised: *rapid prototyping* and *incremental development* [5].

The classical software development approach (the waterfall model) is based upon a series of sequential stages that goes from requirements analysis, through coding and testing, to the system delivery. Here, it is assumed that most of the requirements can be defined at the outset of the project, whereas it is well recognised that requirements instability could easily lead to critical cost and schedule overruns.

Rapid prototyping is method a in which the exact opposite of the traditional software development approach is held true: time and resources are fixed, as far as possible, and the requirements are allowed to change. It is therefore suitable for all those cases in which the requirements cannot be exactly defined at the beginning of the development. For example, when the stakeholders do not have a clear idea of the system to be developed, but this will mature over time, or when different solutions seem to be equally valid and a deeper analysis appears to be necessary. To achieve its goals, rapid prototyping employs user-centred product prototypes, and requires a close collaboration between users and developers. Software prototypes come in different form, including throwaway prototypes, quick-and-dirty prototypes, and evolutionary prototypes, that is prototypes that evolve in the final system. The common idea is to allow the developers to rapidly construct primitive versions of the software system that the users can interact with and evaluate. The obtained feedback is incorporated to correct, refine, and enrich the emerging system properties.

In order to deal with the previously described complexity of the solution space, a rapid prototyping techniques has been adopted to perform our integration study. In particular, rather than developing the CLDP control software directly on the HDD, an evolutionary prototype of such software has been developed. This software model (thereafter referred to as *Virtual HDD*) gave us a powerful tool for the requirements analysis at an early stage, that was usable throughout the full life cycle of the software (evolutionary prototype). The virtual HDD has in fact allowed us to enrich our avionics RIG with the CLDP, and then use the RIG analyse the CLDP operating procedures with the members of the User Group.

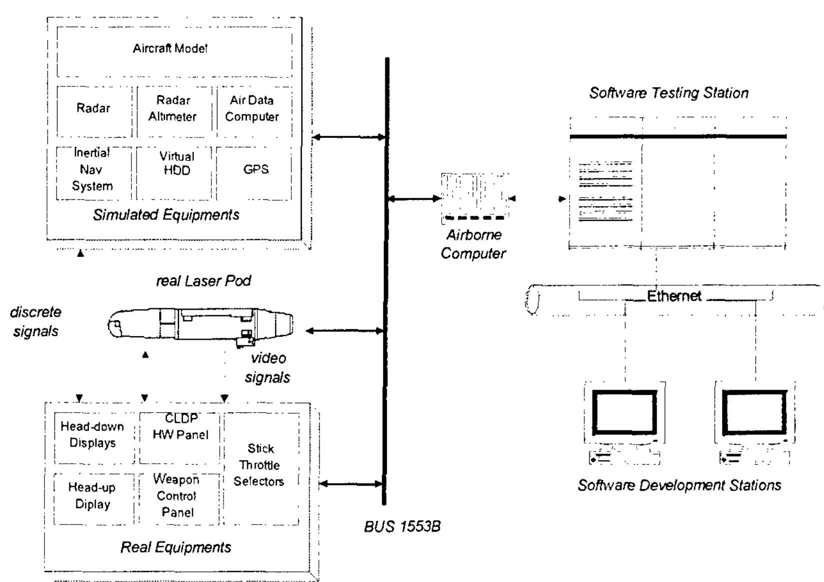

Figure 5: Architecture of the Avionics RIG

A simplified scheme of the architecture of the AM-X Avionics System RIG (ASR) used through the integration study is illustrated in Figure 5. Apart from the Software Development Stations and the Software Testing Station, used to modify the airborne software and test it directly on the BC/MC, the ASR consists of a mixture of real and simulated equipment. For example, while all the main sensors are simulated (Inertial Navigation System, Air Data Computer, Tacan, etc.), a real CLDP is used, together with real units associated with the AM-X mission system MMI (HDD, HUD, switches and selectors, Pilot Stick and Throttle). The MMI allows a pilot to form part of the overall rig, so that the effects of the proposed new weapon system on pilot performance can be determined. It is worth noting that in order to reduce the costs associated with ASR development and maintenance, the ASR has been designed to provide only the capabilities strictly necessary to perform the integration study. The absence of more complex features, as, for example, a wrap-around display to represent the external world, has been overcome by employing especially trained personnel.

The simulated subsystems are realised using a high-level testing tool, i.e. the AIDASS, by ALENIA. It consists of a set of real time VAX computers inter-linked via a VME bus, and equipped with the interfaces necessary to be connected the AM-X avionics system (Mil-bus, discrete and analogue signals). Both the aircraft simulator and the set of sensor simulators have been developed within the IAF Operational Test Centre, by partially customising software created for other projects. As the other simulated equipment, also the Virtual HDD was implemented on the testing tool AIDASS. This not only gave us the possibility of using the Ada programming language (the same adopted in the real HDD) that, combined with an ad-hoc design, allowed us to obtain a software package immediately portable on the real HDD, but also of employing an advanced environment for software debugging.

Although rapid prototyping is a good solution to deal with unstable requirements, it is difficult to apply on big projects, and can easily lead to an explosion of project complexity, and associated risks, whenever requirements instability is not confined to a specific area. For such a purpose, an *incremental development* approach has been adopted in conjunction. In other words, in order to reduce and manage project complexity, the initial "unstable" set of requirements have been divided up into three sub-sets, that is:

- the sub-set A, regarding the CLDP basic control functions (e.g. test functions, CLDP pointing, etc.), and implementing the CLDP interface control document;
- the sub-set B, regarding the integration of the CLDP with the aircraft navigation functions;
- the sub-set C, regarding the integration of the CLDP with the aircraft attack functions.

In Figure 6 it is schematised the software development process adopted to perform the integration study, especially devised to combine the benefits provided by the rapid prototyping and the incremental development techniques.

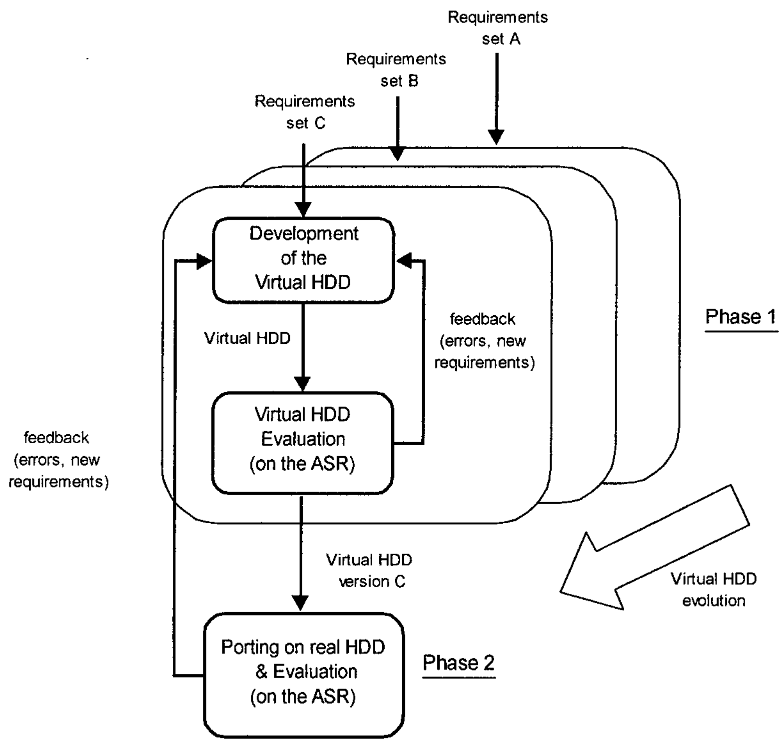

Figure 6: The adopted development process

As shown in Figure 6, such a process is based on two main phases.

During the *phase 1*, the virtual HDD was developed. In particular, first, the Virtual HDD was built by fully developing the sub-set A of the requirements (Virtual HDD version A), then by introducing the sub-set B (to obtain Virtual HDD version B), and finally by introducing the sub-set C (to obtain the Virtual HDD version C). After being developed, each version was evaluated by employing the ASR. The evaluation was performed mainly by the User Group, which was involved in order to validate, correct or improve the requirements already implemented, and to discover new requirements. Depending on the results of this evaluation, more correction and refinement loops occurred. Only when the version C of the Virtual HDD resulted to satisfy the users needs (i.e. the Virtual HDD was a full representation of the desired final system), we passed to the *phase 2*. Here the software implementing the Virtual HDD was ported on the real HDD, and, this, on its turn, was evaluated. As final result, the modified HDD became an "animated" and "validated" requirements document, yet a fundamental component of the final system.

Having defined the development process, we were able to clearly identify and separate the efforts of the various sub-groups of the Project Team, increasing the concurrency within the different project tasks and between this project and other projects. Moreover, the HDD manufacturer was involved to modify the real HDD only at a late stage, when a stable idea of the final system was available, reducing the associated costs and schedule.

The described process regards the development of the software for the HDD. Due in fact to the small amount of changes required by the software of the BC/MC, a more traditional approach was applied in this case. In particular, the BC/MC software was modified to follow the evolution of the Virtual HDD, and to allow its integration on the ASR.

Project Results

Single-Seater or Two-Seater? IAF opted for the CLDP modification to be used by the single-seater version of the AM-X. On the other hand, LGBs are used onto other single-seater (e.g. the French JAGUAR [2]).

The presence of a single crewman faced us with a set of requirements that were not present on the Tornado, where the navigator can dedicate himself to the CLDP operations. We answered to these requirements in two steps:

- a more careful construction of the "Operator Dialogue" (i.e. the sequence of buttons to be pressed to obtain a function) of the MMI, in order to make the use of the CLDP as simple and straight as possible, without reducing the number of available functions;
- a set of facilities to lower the workload of the pilot and to enhance the safety of the operation.

The MMI was implemented by using at the maximum extent the available HOTAS (Hands On Throttle And Stick) commands (e.g. the CLDP LOS is controlled via the same joystick, placed on the throttle, that is already used to point the Radar Antenna). Moreover, to allow the pilot to point the CLDP, looking either inside or outside the cockpit, we used a cross symbol already available on the HUD to mark the same spot looked at by the CLDP camera.

In order to keep low the risks induced by the pilot looking inside the cockpit, at the HDD, an essential attitude indicator is superimposed to the CLDP image, along with alert messages (e.g. "ROLL OUT"), should some basic aircraft attitude, speed or terrain separation limit be violated. The presence of the automatic pilot, and the philosophy of LGB attacks, that foresees medium-to-high-altitude attacks in a context of air-superiority, also support the viability of the single-seat use.

Nevertheless the CLDP modification is immediately portable and fully compatible with the two-seater version of the AM-X. The two-seater will offer the advantage of a dedicated crewmember for the management of the laser pod. It will allow an effective training at low risk, and, also, "co-operative attacks" (one illuminator ship, more carrier ships), for which a dedicate crewmember is deemed essential.

---

2 The JAGUAR uses the same CLDP pod, but it can deliver the AS-30 missile, with a greater stand-off range with respect to the LGBs used by the AM-X.

Quantitative Insights. The final size of the produced software is of 9000 Ada LOC (Line Of Code) for the HDD, and 300 Fortran LOC plus 150 Assembly LOC for the BC/MC. The relative impact of the modification with respect to the total software is low (Table 2). This is a welcome property, which keeps low the risk of introducing new defects and reduces the work of re-evaluating and testing the existing functions.

Airborne Computer	Modified Software	New Software
BC/MC	2%	1%
HDD	1%	15%

Table 2 – Percentages of Modified and New Software

On the basis of the development process described in the previous Section, a more detailed analysis is possible.

The initial release of the Virtual HDD (version A), consisting of about 5500 Ada LOC, 200 Fortran LOC, and 150 assembly LOC, was produced in about 7 months. The personnel involved were, initially, only the members of the Software Development Team. Once the confidence into the technical feasibility of the project was achieved, the User Group was involved to deal with the operative requirements, while the Hardware Support Group updated as required the ASR. Then the first period of evaluation, debug, and re-evaluation of the model was performed.

Having reached a stable version A, we started introducing the sub-set B of the requirements. This phase lasted about 5 months. Then we started the integration of the sub-set C of requirements. The phase ended after about 3 months, therefore the version C of the Virtual HDD (about 10000 LOC, airborne code plus some ancillary code for the RIG) was produced in a 15-month period.

The porting of the Virtual HDD version C onto the real HDD was straight. The only exception was a fine parameterisation of the code due to the different way of numbering the bits within a word, used on the VAX of the virtual HDD and on the Motorola microprocessor of the real HDD. For the porting, two people from the HDD manufacturer were involved, for a limited number of meetings and for a total of 6 days of actual integration. As further confirmation of the quality of the Virtual HDD, and of the adopted development process, the evaluation on the ASR of the modified HDD revealed only some minor defects.

The effort, duration and size of the project are well estimated by the Constructive Cost estimation Model (COCOMO) [6], as illustrated by Table 3, where, for the sake of brevity, only the main results obtained by applying such an estimation tool are reported.

The delay of the project with respect to the schedule provided by the COCOMO equations (about 5 months) is due mainly to pre-emption of personnel for other tasks (about 3 months), and to some bureaucratic delays with the partner industries (about 1 month). In addition, the team was smaller than the estimated one.

Size	10,25 Kilo delivered LOC
Effort	76,02 Man-Month
Schedule	9,99 Months
Average Team Size	7,60 Persons

Table 3 – The COCOMO Model applied to the AM-X / CLDP Integration case

Costs. The costs of our integration study are low, mainly due to the project having been run with in-house resources (personnel and low-cost RIGs), and a small support from the partner industries.

The recurrent costs are quite low, being limited to the reload of some software packages, and to the introduction of the CLDP on/off switch, power supply cables and connectors. The CLDP are basically those already available for the Tornado, so the costs of the logistics can be shared with the other aircraft.

Enhancement of Capability. The need for precision attacks from high altitude dramatically emerged in the current scenarios of peace keeping/enforcing operations, where "surgical" attacks are needed. IAF also needed to enhance the effectiveness of each single aircraft, in a context of a shrinking budget.

The CLDP is a viable answer to the above problems, therefore the benefits/costs ratio of it should be considered high just for operative reasons, also without taking into account the economical advantages of our implementation.

Conclusions

We described a prototype integration of a laser illumination pod onto the AM-X aircraft, in the context of a low-cost, high-confidence-of-success project.

Software can be changed without large industrial facilities and software upgrades can greately enhance an aircraft performances. Our solution was a software modification at 95%, and made large use of software engineering techniques to quickly obtain the desired results at low costs. We consider our experience as positive and successful. The general guidelines emerging from it are the following:

- consider using off-the-shelves equipment and modification of the software, to match new requirements in a cheap a viable way;
- exploit the capacity to blend legacy or available systems and new devices in the path of reducing costs and time;
- use tight collaboration among industry, operating people and engineers of the Air Force;
- employ small, committed groups; with a clear and realistic scope;
- be aware that bureaucratic problems are independent from the complexity of the technical problems. They are functions of the visibility of the project and of the number of groups involved;
- use simulation for assessment & evaluation, but use the real software and hardware for the finalisation of the work, to avoid duplications, delays and costs.

Acknowledgements

We would like to thank all the people that made this project possible, and, in particular, the persons who were directly involved in performing the work: Luca Attias, Marco Cittadini, Mario Solaro, Paolo Calabrese, and Marco Berardinetti.

References

[1] Rivista Aeronautica. Annuario Azzurro 1998. Roma, Italy, 1998.

[2] Thomson. Convertible Laser Designation Pod. France, 1992.

[3] Alenia. AM-X Convertible Laser Designation Pod Operational and Functional Requirements, Issue-3. Torino, Italy, 1992.

[4] Alenia. Preliminary CLDP/AM-X Interface Control Document. Torino, Italy, 1993.

[5] Kan, S. H. Metrics and Models in Software Quality Engineering. Addison-Wesley Publishing Company, MA, 1994.

[6] Bohem B.W. Software Engineering Economics. Prentice-Hall, N.J., 1981.