FINAL REPORT

Grant Agreement Number: **CS-GA-2009-255702**

Project Acronym: **GRA3M**

Project Title: **GREEN Regional AIRCRAFT AVIONICS ARCHITECTURE FOR MISSION AND TRAJECTORY MANAGEMENT**

Periodic Report: **Final**

Project Coordinator: **GMVIS SKYSOFT, S.A.**

TEL: **+351 21 382 93 66**

FAX: **+351 21 386 64 93**

E-MAIL**: jose.neves@gmv.com**

	NAME / COMPANY	DATE	SIGNATURE
Document Author	José Neves / GMV	16/04/2013	
Technical Approval	N/A		
Head of Division Approval	José Neves / GMV	16/04/2013	
Project Management Authorisation	José Neves / GMV	16/04/2013	

Pages: 18

CLEANSKY Topic: JTI-CD-2009-1-GRA-01-001

DOCUMENT CHANGE RECORD

DATE	ISSUE & REVISION	CHANGES	NAME / COMPANY
16/04/2013	1Pr1	Initial release.	José Neves GMV

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.INTRODUCTION

1.1. PURPOSE

This document is the Final Report for the Green Regional Aircraft Avionics Architecture for Mission and Trajectory Management (GRA3M) project developed under the Clean Sky Joint Technology Initiative (JTI) and it cover the period overall duration of the project.

The focal purpose of this document is to report the project objectives and achievements, and the use and dissemination of foreground.

1.2. DEFINITIONS

1.2.1. ACRONYMS

The following table provides a list of acronyms used in this document and in need of a definition to aid the reader in understanding the overall context.

ACARE:	Advisory Council for Aeronautics Research in Europe
AADL:	Architecture Analysis and Design Language
ADS-B:	Autonomous Dependent Surveillance Broadcast
AIDA:	Architecture for Independent Distributed Avionics
API:	Application Programming Interface
ATC:	Air Traffic Control
ATM:	Air Traffic Management
AS:	Airborne Surveillance
ASAS:	Airborne Separation Assistance Systems
COTS	Commercial off the Shelf
CCM:	CORBA Component Model
CPM:	Core Processing Module
CPIOM:	Core Processing Input/Output Module
DDS:	Data Distribution Services
DME:	Distributed Modular Electronics
EUROCAE	European Organization for Civil Aviation Equipment
FP:	Framework Programme
IDE:	Integrated Development Environment
IMA:	Integrated Modular Avionics
IMA1G:	IMA First Generation
IMA2G:	IMA Second Generation
LRU:	Line Replaceable Unit
KOM:	Kick-Off Meeting
M:	Milestone
MM:	Man Month

MDA:	Model Driven Architecture
MOS:	Module Operating System
MTM:	Mission and Trajectory Management
MW:	MiddleWare
PM:	Person Month
POS:	Partition Operating System
QoS	Quality of Services
R&D:	Research and Development
RDC:	Remote Data Concentrator
REU:	Remote Electronics Unit
RPC:	Remote Power Controller
RTCA:	Radio Technical Commission for Aeronautics
SWOT:	Strengths, Weaknesses, Opportunities and Threats
WP:	Work Package

2.REFERENCES

2.1. APPLICABLE DOCUMENTS

Applicable documents are defined as being documents which are needed to complete the contents of this document. They are referenced in this document in the form [AD.X].

REF.	TITLE	CODE	ISSUE / REVISION	DATE
[AD.1]	GRA3M Grant Agreement	CS-GA-2009-255702	-	25/10/2009
[AD.2]	GRA3M DoW	JTI-CS-2009-1-GRA-014-001	V2.2	25/10/2012
[AD.3]	Clean Sky Joint Undertaking Call for Proposals	SP1-JTI-CLEAN SKY-2009-1	-	15/06/2009

Table 2-1: Applicable Documents

2.2. REFERENCE DOCUMENTS

Reference documents are defined as being documents that are not applicable but rather improve the readers understanding of the overall context or for other reasons deemed important. They are referenced in this document in the form [RD.X].

REF.	TITLE	CODE	ISSUE / REVISION	DATE
[RD.1]	Project Management Plan	GRA3M-D01	1-A	23/04/2010
[RD.2]	Quality Management Plan	GRA3M-D02	1-A	23/04/2010

Table 2-2: Reference Documents

3.PUBLISHABLE SUMMARY

3.1. EXECUTIVE SUMMARY

The main objective of this project was to study different possibilities of implementing the Green Regional Aircraft Avionics Architecture for Mission and Trajectory Management (GRA-4.1 MTM) according to the state-of-the-art, and beyond, and to analyse the strengths and weaknesses of the chosen approaches. The requirements of the MTM were, therefore, the main input to the project and their successful analysis was the first milestone of the project. Additional requirements were raised from overall objectives of CleanSky and related programmes like SESAR, mainly given as parameters to the SWOT analysis that were performed at the end of the study.

Based on the requirements, a market survey was performed to select possible hardware and COTS components that could be used for the implementation of the MTM. The requirements were analysed to an extent that allowed performing first resource usage estimations. Without detailed architecture studies, these estimations were premature. For the purpose of the task, the output of the survey was a list of component descriptors for all possible components. The attributes of the descriptors contained the parameters to the final analysis that were directly applicable to the components, like weight, volume, power consumption, mean time between failures etc. The market survey that was developed included components for all types of architectures to be studied, i.e. federated and IMA.

Based on the requirements and the available components, possible architectures were studied. Three architectures were taken into account: the federated architecture, current IMA approaches and expected future IMA2G concepts, under investigation in the DIANA and SCARLETT FP projects. The results of this task presented possible implementations of the MTM requirements on the available components, revealed during the market survey. The output of this task was presented using network diagrams, UML/SysML diagrams and AADL diagrams. Finally, the descriptors of the components, used in the architectural studies were compared by means of a SWOT analysis. The results of the analysis were presented, both, in form of tables focusing on the quantifiable difference and a textual report focusing on the different objectives of the architectural approaches.

3.2. PROJECT CONTEXT AND OBJECTIVES

In the context of WP4 of the CleanSky Green Regional Aircraft activity, the GRA3M project aimed at analysing possible architectures meeting the requirements of an enhanced Mission and Trajectory Management (MTM) system. The overall objectives of the CleanSky programme are tightly coupled with the goals of the SESAR programme. Where CleanSky aims at more efficient aircraft technologies for fuel and noise reduction, SESAR accounts for air traffic growth, estimated close to a duplication of today's air traffic by 2020. In both programmes, MTM is seen as the key technology for a more efficient flight planning and operation by means of:

- Better usage of capacities
- Reduction of delays
- Enhanced predictability
- Enhanced flexibility
- Enhanced cost effectiveness.

For CleanSky, additionally, the reduction of fuel consumption by means of empty weight reduction, without reducing today's safety standards, is an important requirement in the current context.
The introduction of new functionalities and smarter on-board applications as part of a more efficient MTM system is limited today due to various factors. The main limitations are

- Weight and volume, which limits the extension of on-board equipment (also contradicting main objectives of the CleanSky programme);
- The increasing role of software as today's main cost driver (in development, integration and maintenance) in on-board electronics;

- Certification interdependencies, causing the need for re-certification of existing components by integrating new ones.

The architecture to be chosen for the implementation of the MTM software should therefore take those constraints into account by looking at recent developments in avionics technology, mainly in the domain of Integrated Modular Avionics (IMA). IMA allows the introduction of standard hardware components and sharing these components between functions from different suppliers and even of different criticality. IMA, additionally, helps to build a more efficient development process, reducing mainly integration costs (see below section B1.1) by focusing on design and early validation. IMA also allows incremental certification to ease adding new functionality to an aircraft system without the need to re-certify all existing components.
The GRA3M project analysed the strengths and weaknesses of both, federated and IMA-based technologies, to ensure a solution that supports the CleanSky objectives. In detail the project:

- Analysed the functionality of the MTM based on the requirements specification developed in the course of GRA WP4.1 (High level requirements for MTM);
- Performed a market survey to obtain an overview on available components and their costs, weight, size, power consumption etc. The market survey has taken components for both kinds of architectures into account: federated and IMA;
- Study the possible architectures for implementing the MTM according to the given requirements; the study took both kinds of architectures into account: federated and IMA.
- Analysed the Strengths, Weaknesses, Opportunities and Threats (SWOT) of these architectures based on the information gathered during the previous tasks.

3.3. PROJECT RESULTS

The technical deliveries D2, D3, TN4 and D5 constitute the main results of the project. Starting from the requirements analysis D2, a market survey was performed to collect data about major trends on the market and components that can be used to implement CleanSky MTM following a federated or IMA paradigm; the results were assembled in the D3 delivery. The technical note TN4 presents the results of the architectural studies. TN4 was finally used for the SWOT analysis that is presented in report D5.
In conformance with the DoW, the team decided to present the analysis in textual form and as models. As modelling language, SysML and UML were selected. This selection reflects the level of abstraction of the requirements at the beginning of the project as well as the needs of the SWOT analysis.
In the following subsections, the results are described in more detail.

3.3.1. REQUIREMENTS

In the scope of GRA3M D02 Deliverable document, the team has identified use cases for the avionics systems. These use cases will help to identify the relations between sub-components, and in particular, procedures that are implemented on top of these components.

We also extracted requirements from input made available to the project by Alenia. The requirements were added to the architecture model by means of SysML requirement diagrams. The main aspect is their logical link to components in the architecture. The model may be used to implement validation procedures (using e.g. the Object Constraint Language) to check if the constraints expressed in the requirements hold.

Important requirements that have been described included:

- ❑ The Multi-Criteria Departure;
- ❑ On-board weather radar;
- ❑ The Continuous Descent;
- ❑ The steep approach.

These requirements imply:

- ❑ The use of models describing aircraft emission and noise profile and population data;
- ❑ Radio-based data communication;

This document is produced under the CLEANSKY Joint Technology Initiative (JTI).

- On-board weather radar equipment;
- Integration of satellite-based positioning and navigation systems.

3.3.2. MARKET SURVEY

Within the GRA3M D03 Deliverable, important technology trends have been analysed with respect to their effect on greening factors, such as weight, volume, noise and energy consumption. Time frames for possible introduction of the technology into on-board systems were given. The time frame was estimated according to the TRL which, in its turn, was evaluated according to activities and applications using the respective technology today. Each section summarises the results at the end.

Very different technologies have been studied. The main tendencies are

- the transition from federated architectures to IMA and next generation IMA;
- the transition from ARINC 429 to AFDX;
- the introduction of other bus technologies, e.g. TTP and optical fibre;
- the introduction of multi-core architectures;
- the introduction software-defined radio.

For many of these technologies, clear tendencies in reduction of weight, volume and energy consumption were shown, and in some cases, *e.g.* optical fibre, it was possible to come close to concrete figures. Since technology providers are today working on products based on these technologies that are expected to be competitive advantages in the near future, concrete figures are, however, difficult to obtain.

It was indeed difficult to obtain all values of interest for components existing on the market today. One reason for this is that certain factors, *e.g.* weight, depend on the system in which the component is to be integrated. The number of cables needed for a network, for instance, depends on the network topology (peer-to-peer, token ring, etc.). This, however, can only be decided with concrete functional and RAMS requirements. For other parameters, *e.g.* price and maintenance policy, depends on commercial factors, like the number of instances of a component eventually purchased, the relation of the customer to the provider and the stage of involvement of the provider in the programme. Since no concrete business case could be presented, providers could not provide clear indications concerning such parameters.

The architectural studies and the SWOT analysis, that used this document as input, have to estimate future developments on the basis of existing components. The study on technology trends provided tendencies that were helpful for these estimations. More difficult is the consideration of factors for which providers did not want or could not provide further information. Here, the experience of the project team with comparable components was used. The main parameters for the SWOT analysis, however, shall be those parameters with direct influence on the greening of aircrafts, weight, volume, noise and power consumption.

3.3.3. ARCHITECTURAL STUDIES

Within the Architectural Studies**Error! Unknown document property name.** document, GRA3M TN04 Deliverable, three architectures have been studied. We started with a conventional federated architecture, migrated to IMA and extended the IMA architecture to an IMA2G approach by exchanging COTS components by remote components with tailored processing capabilities. Following this path, we achieved to reduce weight and power consumption. These savings were achieved on components and cable weight. The overall savings are listed in the following table:

	Weight				Power			
	Total		Without Radar and EFIS		Total		Without Radar and EFIS	
	kg	Percentage	kg	Percentage	w	Percentge	w	Percentage
Federated	79,5		46,9		541,4		237,4	
IMA	69,24	12,91%	36,64	21,88%	498,4	7,94%	194,4	18,11%
IMA2G	59,36	25,33%	26,76	42,94%	432,4	20,13%	128,4	45,91%

Table 3: Overall Savings

The table lists the values for weight and power consumption. The difference to the original federated architecture is given as a percentage according to the value of the federated architecture. We see, for example, that IMA and IMA2G reduce the weight for about 10kg and 20kg; this corresponds to 13% and 25% saving. The products used for weather radar and the display system have not been changed. It was assumed that these systems are part of the avionics infrastructure, also used by other systems. If we add out these values, we see weight saving of 22% and 43%. The values for reduction of power consumption are very similar.

Much more important than these savings, however, is the structural change going along with the paradigm change of the architecture. In the federated approach, an additional black box had to be added for each new component. Weight and power consumption increase for a factor that depends on the product and is, hence, in principle unknown. This is illustrated especially by the network: For each new component added to the ARINC 429 network, used in the federated approach, new physical connections, *i.e.* cables, have to be added to the system. The material to be added corresponds to the number of connections that are needed between the different component and the distance of the units from each other. With an AFDX network, a single line (per redundant network) from the new component to the closest switch is sufficient. The IMA and IMA2G architectures with an AFDX network are, thus, more scalable. Its growth is predictable and based on building blocks that are added to the system.

GMV's team also suggested a migration path from the original federated approach to the IMA2G approach. This migration, despite of implying some radical intersections, preserves some characteristics of the original architecture and even maintains some components that are assumed to be difficult to substitute, namely the EFIS display system and the weather radar. In the second step, migrating from IMA to IMA2G, some of these components were radically changed by substituting fully integrated COTS products by standard building blocks with independent solutions installed on them.

3.3.4. SWOT ANALYSIS

GRA3M D5 Deliverable provided a SWOT analysis accompanied by analysis of individual impact areas related to the criteria introduced in the DoW and a quantification analysis comparing the two main options of achieving reductions in weight and power consumption with federated or IMA architectures. We have shown that there are good opportunities in IMA, like reducing weight and power consumption, shorten time-to-market and ease obsolescence management, that combine well with the strengths of the industry, in particular the investment in research and development as well as experience obtained with IMA in practice.
There are, however, also weaknesses, in particular the need to change business practices with regard to system development, certification, maintenance and obsolescence. Additionally, there are threats related to the complexity of the IMA approach. The most sensible threat is certainly related to safety. Other threats impact certification, the new market and the need for technological innovation like the development of a platform.

On the other hand, there is the federated approach with strong arguments to maintain the known environment with its known technology and market and its stable business practice. The main weakness is that the industry will not be able to address the profound challenges of the future, such as the growth of air traffic and the related impact on environment. There is also the risk that the industry will not develop knowledge in what appears to be the upcoming standard technology. The main threat is, accordingly, the unpredictable growth of avionics systems with federated technology together with growth of air traffic; these factors may endanger the political goal of the European Union to reduce CO_2 emission. Furthermore, opportunities associated with a switch to the IMA technology, may turn into threats for companies that stick to the traditional technology. In particular the low scalability and the longer time-to-market may introduce serious competitive disadvantages.

In the following, it is described some recommendations, including mitigations for risks, which we see as the main results of this study:

1. The results suggest that IMA is a very promising candidate for a future on-board system with huge potential to reach the main goals of CleanSky in the domain of avionics architecture and, additionally, to achieve other enhancements like shortened time-to-market, incremental certification, general scalability of the systems and better obsolescence management.
   It is therefore **recommended to adopt IMA architectures** for regional aircrafts.
2. The technology is not yet completely dominated. There are technical risks and uncertainties related to safety analysis, certification and the market. Those risks must be addressed.
   We therefore **recommend continuing and intensifying research** in the domain of IMA.
3. Even with this said it shall not be forgotten that there are a lot of interesting technology developments in research and the market place. Partly, such technologies have been described in the market survey. Many innovations, such as new languages, formal methods, model-driven engineering, *etc.* are complemental to IMA. It is possible, however, that some technologies, such as multi-core, for instance, evolve into alternative approaches.
   We therefore recommend **continuing research in technological alternatives**.
4. It appears that it is difficult to overcome the uncertainties on the market with research activities only. As discussed before, the lack of transparency seems to be related to concerns of providers to lose investments in future technology by giving knowledge about current programs and products related to IMA to potential competitors. A more promising way to break this *information barrier* appears to be a project with the goal of building a real system. With the perspective of having a product in an aircraft programme, it is more likely that vendors are willing to give details on their developments.
   We, thus, **recommend planning a subsystem based on IMA in a real aircraft programme**.
5. At the same time, risks related to introducing new technology into a real aircraft, must be mitigated. It is therefore not recommendable to start with the complete avionics infrastructure based on IMA. Instead, the federated architecture shall be kept and only subsystems shall be initially migrated to IMA. This is the way that was chosen by Airbus in the A380 programme, for instance.
   We **recommend building selected subsystems with the IMA approach to gather experience** with this technology.
6. An important aspect of IMA, and in particular of IMA2G, is the idea of a *platform* that consists of a homogeneous tool chain for design, configuration and software build as well as a set of hardware and operating system targets, including the network. The platform eases development, certification, maintenance and obsolescence management and will thereby help to reduce cost, effort and time-to-market. Many of the advantages of IMA will not manifest without a defined set of standard components to be reused across systems and aircrafts.
   We therefore **recommend investing research on possible platform technology** and starting the integration of a platform as soon as possible.
7. In this context, it is advisable to study research results in the area of IMA2G, where the notion of platform is stressed. There are in particular two projects that may be of great interest: SCARLETT and DIANA. SCARLETT is mainly focused on the integration of a platform addressing all aspects of system design and execution. Important aspect, here, are predictable networks and I/O components. Both aspects had little attention in the definition of the first generation of IMA. They are, however, of vital importance for the development of real systems.
   Where SCARLETT is looking at the whole system, DIANA focused more on software aspects. Major points of interest in the context of the DIANA project are (i) the definition of a unique tool-chain based on modelling, formal methods and modern programming techniques, (ii) platform services,

such as databases, byzantine fault resilience or system-wide health monitoring, to build a common application infrastructure and (iii) components-oriented software architectures for partitioned systems.
We recommend studying projects in the area of next generation IMA, in particular results from the SCARLETT and DIANA research activities.

3.3.5. OVERALL CONCLUSIONS

The objective of the project was to study different types of architectures for avionics systems implementing the CleanSky mission and trajectory management requirements and to perform a SWOT analysis with regard to the goals of the CleanSky undertaking, i.e. the reduction of environmental impact.

The project encountered some technical challenges, not foreseen at project start which led to a delay and to effort expenditures significantly above the initially planned budget. The project team was able to face and to overcome these problems and, in consequence, reach the project goals.

The results are presented in four contractual deliveries, presenting the analysis of the CleanSky MTM requirements, the market survey, the architectural paradigms studied in the scope of the project and, finally, the SWOT analysis based on these studies. The analyses performed during the tasks used modern system development methodology, in particular models representing requirements, use cases and architectures. The Market Survey provided a profound analysis of current trends in avionics technology as well as a huge base of single components of different categories. The requirements baseline for these studies reflects the CleanSky MTM requirements; care has been taken to consolidate this requirements base with the current state of the CleanSky undertaking. Finally, the SWOT analysis took all these aspects into account and concludes the study with a set of recommendations for the green regional aircraft avionics architecture for mission and trajectory management.

3.4. DISSEMINATION ACTIVITIES

GMV has developed several dissemination activities under the scope of the WP1 (Managemetn). The main objectives of such activities were to ensure a systematic dissemination of the project outcomes among the aeronautical community (public dissemination).

3.4.1. EVENTS

3.4.1.1. Farnborough Airshow

There was not a direct presentation of the GRA3M Project in the Farnborough Airshow from 2010 but, actually, one project meeting, between GMV and Alenia, was performed during this event.

3.4.1.2. Aerodays in Madrid

In 2011 Mr. Tobias Shoofs, Project Manager for GMV for GRA3M, performed a project presentation of the results of GRA3M, during the European sixth Aerodays, held from 30th of March to 1st April 2011 in Madrid.

3.4.2. PRESS RELEASES

3.4.2.1. Semana Informática

It is common practice for articles associated with GMV to be included some of the editions of the magazine «*Semana Informática*». Therefore, a set of articles stating GMV's participation in the GRA3M project was respectively publicized such as, the article entitled "*GMV vence contratos de Segurança Marítima e Aviónica Modular*" (Semana nº 965 de 5 a 11 de Março de 2010).

3.4.2.2. Portugal Global

It is common practice for articles associated with GMV to be included some of the editions of the magazine of AICEP an Agency of the Portuguese Ministry of Economy. Therefore, a set of articles stating GMV's participation in the GRA3M project was respectively publicized in the Portugal Global website.

Webpage: http://www.portugalglobal.pt/PT/PortugalNews/Paginas/NewDetail.aspx?newId=%7B7B64E030-33A3-4F73-B317-4B4E88A50E90%7D

3.4.3. WEBSITES

Websites are fundamental sources of information capable of effectively reaching a sizeable and multicultural audience. It is common practice for GMV to use its own website (http://www.gmv.com.pt) to convey important information to the general public including events and news deemed more relevant and explicit to the company.

GMV publicizes imperative information as an integral part of the news section concerning projects for which the group plays a participative role as sole implementer or a consortium contributor. The following figure provides a snapshot example of the present day layout whereby one can easily locate the news highlights on the right-hand side of the page.

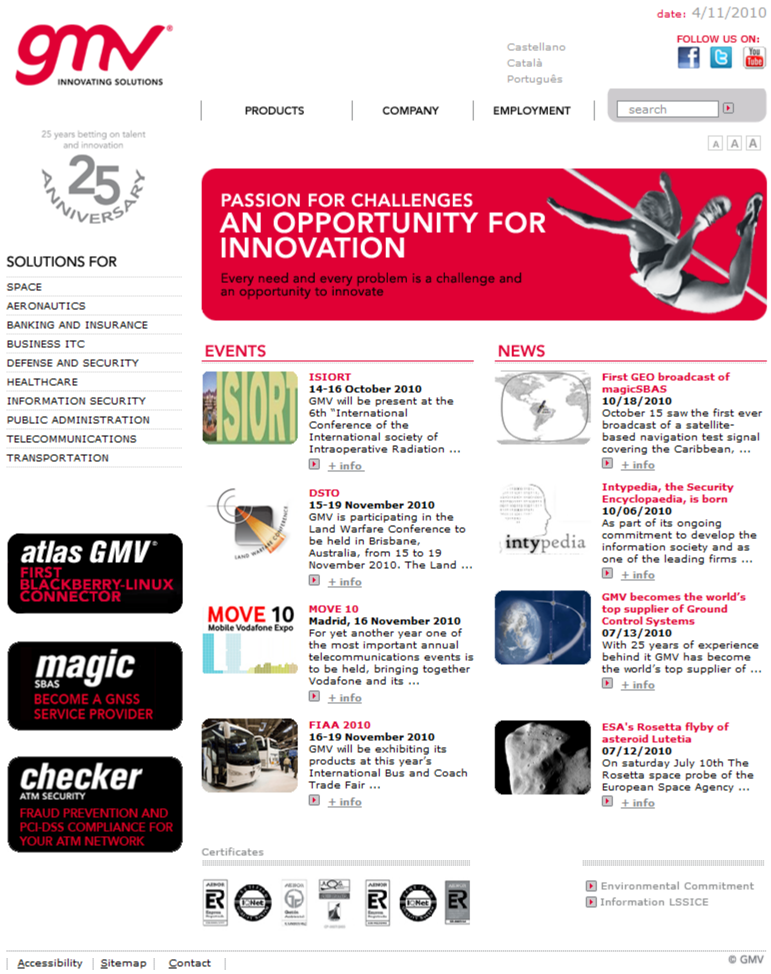

Figure 3-1: GMV's Website Snapshot

Apart from the news highlights depicted on the home page, GMV has a dedicated webpage that relays, amongst other things, the articles released to the press according to the release dates. One article through which GMV's participation in the GRA3M project was portrayed in GMV's webpage:

Webpage: www.gmv.com.pt

3.4.4. INTERNAL NEWS MAGAZINE

GMV circulates amongst all employees the monthly issues of its internal news magazine whereby it portrays the group's worldwide involvement in a myriad of markets, through the innovative and technological projects developed, and vital social events. A relevant project deemed news worthy is highlighted in the magazine by essentially offering the audience an overview of the project describing its nature, purpose, client(s), consortium (if applicable), and in general how it will help shape the future.

Thus, as predicted, GMV's participation in the Cleank Sky programme and namely in the GRA3M project was revealed on issue Nº44 dated April 2010 which is actually available to the public and viewable under the subsequent web-link:

Web-link: http://www.gmv.com.pt/empresa_GMV/comunicacion/boletin_corporativo/revista_44.pdf

3.4.5. GMV ANNUAL REPORT

GMV circulates amongst its clients and partners its Company Annual Report. A relevant project deemed relevant to the organisation is highlighted in the Report by essentially offering the audience an overview of the project relevance and how it will help shape the future.

GMV's participation in the Cleank Sky programme and namely in the GRA3M project was revealed on the 2009 issue which is actually available and viewable under the subsequent internal web-link:

Web-link:
http://incorporate:8421/ES/ComunicacionInterna/Publicaciones%20GMV/informe_anual_09_ING.pdf

END OF DOCUMENT