SYSTEM USING AUGMENTED REALITY FOR MAINTENANCE, ASSEMBLY, TRAINING AND EDUCATION

STARMATE

PUBLIC REPORT v2.0

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I. EXECUTIVE SUMMARY

This document constitutes the second public report of the Starmate (IT 10202) project. This project started in January 1999 to end in March 2003. It was funded within the EC R&D 5th framework program. The partners of the consortium were :

- Thomson-CSF Optronique (now called Thales Optronique S.A.), France : co-ordinator , end-user & developer
- CASA (now EADS), Spain, end-user
- TECNATOM, Spain, end-user
- Dune, Italy, HW developer
- ZGDV, Germany, SW developer
- CSSI, France, SW developer
- The last partner named IFF, Germany, has left the project after one year.

STARMATE project aims at specifying, designing, developing, and demonstrating a product dedicated to computer guided maintenance of complex mechanical elements.

This document first presents the goal of the project, providing an insight on the technical content of developments. It describes how the results of the project will be used beyond the end of the project. It describes the workplan and provides elements on the progress of the project. Finally it explains the co-operation within the project and provides the list of dissemination actions undertaken up to now.

II. PROJECT OBJECTIVES

II.1. GENERAL OBJECTIVE

STARMATE project aims at specifying, designing, developing, and demonstrating a product dedicated to computer guided maintenance of complex mechanical elements. The system will provide 2 complementary functionalities :

- user assistance for achieving assembly/de-assembly and maintenance procedures,
- training to assembly/de-assembly and maintenance procedures.

The system relies on augmented reality technology to provide more flexibility in working methods while preserving user mobility in context where access to conventional documentation is cumbersome. It will improve work environment user-friendliness. It will allow user to access full documentation and manuals directly registered to his working environment. Visual and audio augmentation are used to guide the user through the right procedure to apply. The system is controlled through both speech and a pointing device system.

II.2. SHORT TERM/LONG TERM OBJECTIVES

Work is being achieved according to ISO certification of implied industrials. Each partner is responsible for providing well-circumscribed elements of the system.
The system is being developed from off the shelf SW and HW where possible. In particular, display devices and voice recognition system have been purchased on the market. The system has first been specified in detail. Then building blocks have been designed, implemented and unit tested. Then building blocks are being integrated into the system.
The product is being developed into several releases of incremental functionalities. Hence, the project life is divided into several integration phases.
Result expected from the project is a product that will be sold by TOSA and used by TOSA (optronic), EADS (aeronautic) and TECNATOM (nuclear) to assist and train their workforce.

III.TECHNICAL OBJECTIVES

At the end of the project, the developed product will provide user's assistance while performing assembly/de-assembly and maintenance operations on mechanical systems. The product will also help workforce train to achieving assembly/de-assembly and maintenance procedures.

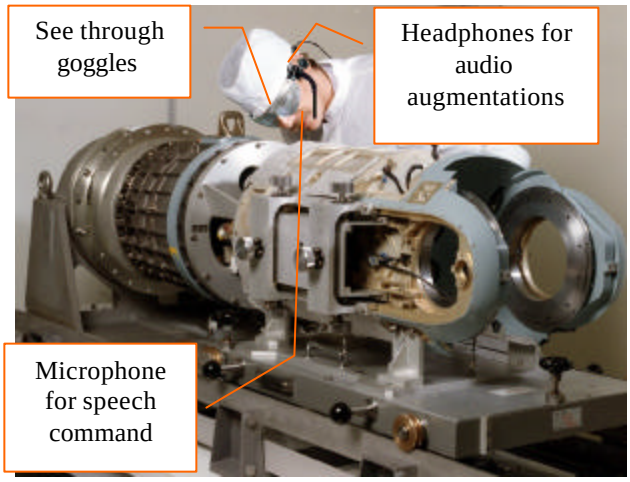
The project decomposes into the following work:

- Technology development, integration and research on usability,
- Demonstration of use.

The measure of success of the project will be to have, at the end of the project, a system for computer-guided maintenance providing the functionalities described below.

III.1.TECHNOLOGY DEVELOPMENT, INTEGRATION AND RESEARCH ON USABILITY

The product will be dedicated to applications where access to conventional paper or IETM[1] documentation is cumbersome. It aims at bringing digital technical manuals, construction files and maintenance procedures within the workplace. It will rely on augmented reality to document working environment with visual and audio augmentation elements. These elements will guide the user through the right procedure to apply, while performing maintenance.



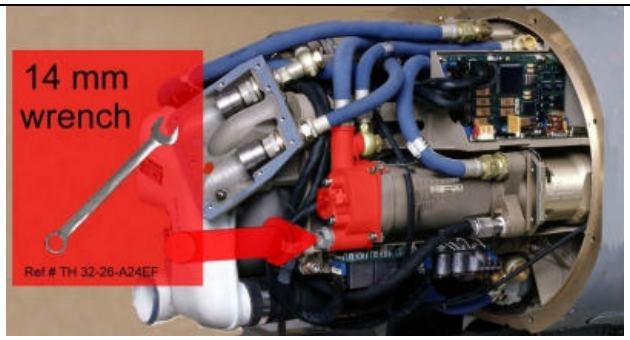
The user will be equipped with :

- See-through goggles (STG) allowing to see the real environment and synthetic augmentation elements at the same time.
- Headphones (HP) providing additional audio information.
- Microphone (MIC) connected to a speech interpretation system.
- A virtual pointing device (VPD) allowing the user to designate objects in his environment.
- A positioning device –not represented here-.
- A belt-mounted data communication unit (BMCU) assuring data transmission between the user and the rest of the system.

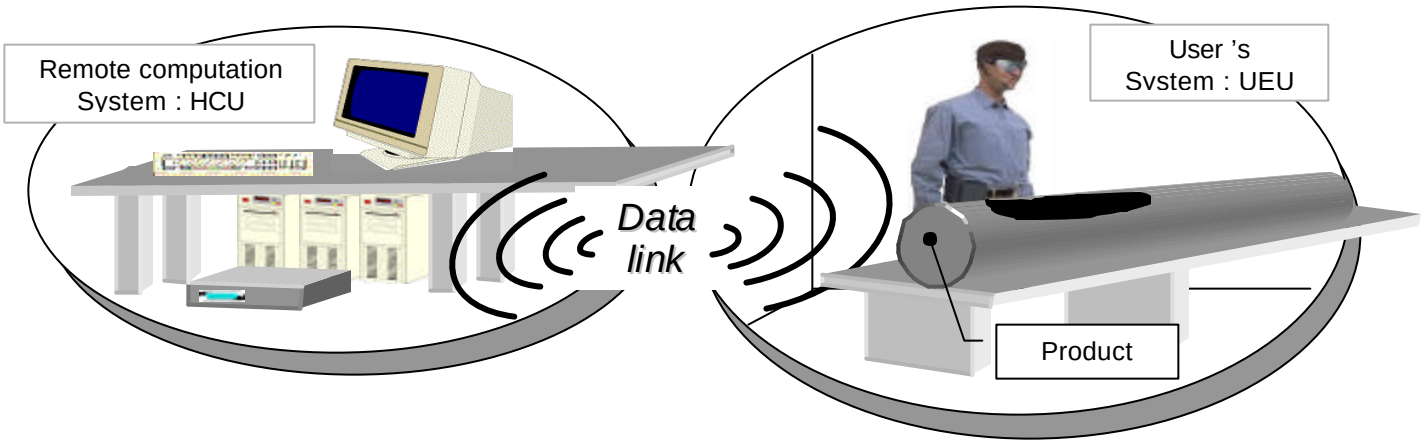
Visual augmentation elements (augmentations) will be registered, in real time, to the scene observed in the STG. Therefore, augmentations will remain at the right visual place in space when user moves his head. Registration of augmentations will be performed by tracking the 3D positions of the user's head and of the elements he works with. The user will control the system via the MIC and pointing system. These elements will allow the user to query the system for information regarding manipulations to be achieved (called procedures).

[1] IETM: Interactive & Electronic technical manuals: systems based on CDROMS and PC's for technical documentation.

Images below provide an example of what the user sees in his STG (See Through Goggles).

	
Transparency view allows seing inside objects without dismounting them. In the present case -cryogenic engine-, the engine bonnet is opaque in reality. However, by registering 3D model projections of the engine parts over their real counterparts, user has the illusion to see inside the engine without dismounting it. In this illustration, user has queried the system to display (in red) the intake of the cryogenic primary pump to get an idea of where he will operate later.	Later in his intervention, the user accesses information relative to assembly, disassembly or maintenance procedures. For instance, he may need to know the kind of tool necessary to dismount a given bolt. In the illustrated case, the wrench type and the supplier's reference are provided to the user through augmentation elements registered to the scene.

The image below provides an overview of the full system. It composes of standard hardware (HW), available in the market. The system splits into 2 separate parts: the user equipment unit (UEU) and the remote heavy computation unit (HCU). Communications between UEU and HCU will be assured by a wireless or optical fibre datalink. User will wear a belt-mounted communication unit allowing him to be mobile and free of movement.



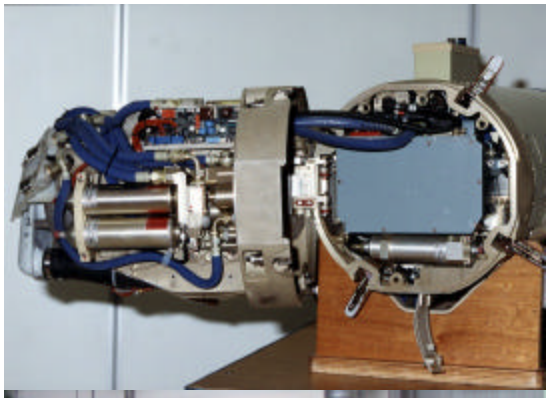
Overview of the system to develop

During work, the user physically interacts with the -real- product to maintain. He has hands free and is guided step by step through the right procedure. Therefore he does not have to memorise complex procedures by heart. All information he needs is directly provided within his working environment and registered to reality.
The system is scalable in terms of supported products. It is customisable to the level of competence of the user.

III.2. DEMONSTRATION OF USE

During the project the system will be demonstrated, in real work situations, on three end-users applications. These end-users will have to control and to validate the system' s functionalities, and particularly, the pertinence of the maintenance scenarios.

- TOSA will be the first end-user. He will use the system in the context of optronic products maintenance & training to maintenance (e g: those illustrated in above images).



- EADS will use the system in the context of aeronautics construction for assembling wings of a famous European aircraft.

- TECNATOM will apply the system to maintenance on complex pumps and turbines used in nuclear power plants. One of these turbines is illustrated in the figure beside.

After project completion:

- TOSA will sell the product in order to widen his offer in terms of maintenance products for optronics equipment.
- EADS will make use of the product to extend applications in aircraft manufacturing.

- TECNATOM will make use of the product to extend its range of maintenance services.

IV.WORK PROGRESS OVERVIEW

This report describes the work achieved during the first 4 periods of the project.

StarMate project officially started on January 1st 2000. However, on a common agreement with the EC, the project work actually started on March 1st 2000.

As planned the work was split into the following phases:
- Initiation of the work
  - Assessment of the risks + determination of actions to alleviate them
  - Internal organisation in the consortium
- Specification of the work
  - Specifications of the system architecture SW and HW (high level specification)
  - Specification of documentary structure & development tools
  - Detailed specification of each module of the system independently
  - Detailed specification of the system HW
  - Detailed specification of end-users applications
- Development
  - Development, testing & validation of each module independently with respect to the constraints of the whole system
- Integration
  - Integration of the modules together, testing & validation
- Deployment of the system at each end-users' place
- Demonstration of the system

In parallel, the ongoing tasks were
- Investigation of ongoing projects or initiatives related to StarMate work.
- Dissemination on the project objectives and work.
- Elaboration and maintenance of Starmate Web site. (http://vr.c-s.fr/starmate/)

A first demo of the system has been made in July 2001 on TOSA application, the second demo in December 2001 during the IST exhibition in Dusseldorf, on TECNATOM application.
The two demonstrations were the occasion for undelining the points that should be improved in the system as well as its good aspects. In a document written in January 2002, all those points are summarized and used as a basis for future developments.

Apart from the preparation of the deployment of the system to Madrid, at the Spanish end-users site, the fifth period of the project was dedicated to the following main aspects :
- Software improvements of the system :
  - The work on the SW modules was pursued.
  - Some parts of the architecture of the system were renewed to fit the improvements expected.
- Hardware improvements :
  - A new datalink was build, integrating all the signals needed by the system. The stress was laid on its robustness and on its capability to transmit all signal to a distance of 10meters without loss of signal.
  - A new headset was designed and almost entirely build. The objective is to have something more robust (no distorsion), more ergonomic and capable of being used in any configuration of the system. The tracking system in particular shall be indifferently magnetic or optical.
  - A generic stand was designed & build so as to carry the equipment needed by the three end-users applications : cameras, Infra-Red spots, lights, magnetic trackers… Its objective is to ease the installation and move of the whole system, in all possible configurations.
- Market Analysis:
  A lot of work has been made on that point. Some of the partners, and particularly TOSA have contacted diverse companies coming from activity sectors very different (so as to have a wide overview of the market). A presentation and a demonstration were the first step to active discussions about Starmate product but also about maintenance tools in general.

V.WORK PLANNED FOR THE NEXT PERIODS

The deployment phase is almost prepared integrally. That means the database and the scenarios related to EADS and TECNATOM applications are about to be ready. The last step now will consist in the installation of the system in Madrid.

The integration of the optical tracking system is as well almost done. Now is the time for validation and intensive testing of that module as part of the global system.

The last period of the project will be dedicated to the finalisation of the developments, and the global improvement of the system, as well as the continuation of market analysis work & eventually preparation of Starmate commercialisation.

VI. EXPLOITATION OF RESULTS

VI.1. PLANS FOR DISSEMINATION OF RESULTS BY THE CONSORTIUM AS A WHOLE

For the consortium as a whole, plans for dissemination of the results produced in StarMate project are the following.

Maintain a web site presenting the project. CSSI will maintain this website. Other partners will contribute to this work.
Disseminate on the project through services of the Community e.g. prosoma.
Publish results in international scientific revues and through participation to international conferences.
Establish links to European projects and companies having common interests with StarMate.
Promote the product developed in the project through media (corporate revues, TV programs, etc…).

VI.2. PLANS FOR EXPLOITATION OF RESULTS BY EACH PARTICIPANTS

VI.2.1. TOSA

Product orientation of the project arises from TOSA customer strong expectations. These expectations have only been described briefly in this proposal because of lack of space. However, the product described in this proposal has an identified market, forecasted to be significant.

- Exploitation strategy :

A thorough market analysis has been carried out this year by TOSA. It was mainly based on contacting companies coming from very different sectors of activity with the following objectives:

- Make the project being known in the world of maintenance & training,
- Collect end-users reactions about the system & their expectations regarding systems dedicated to maintenance assistance,
- Analyze the market in terms of commercial opportunities for Starmate.

The results of this analysis are used as a basis for the further developments of the projects as well as the orientations to take in terms of commercialisation of Starmate product.

VI.2.2.CSSI

CS, which develops high-end simulators and virtual prototyping software for the various industries (from aerospace to museums and theme parks), definitely benefits from the development of the Starmate system.

- Exploitation strategy :

The exploitation of the system is being held around the following two main axes:

- know-how and experience acquired through the development of the Starmate project are considered as important technological spin-offs for the production and integration of customised applications and services.

- Starmate key concepts (Augmented Reality, tracking) and components (natural user interface, XML scenario based management) are going to be integrated, in a similar way, in relevant VR products and projects. Thanks to a close co-operation with TOSA, these concepts and components, which are critical in computer sciences field, may be applied to projects for prototyping and training connected to business with a major aerospace client company.

VI.2.3.TECNATOM

Initially, TECNATOM intend to make use project results and experience gained to develop AR based applications on maintenance training.

In a first stage, STARMATE will be used as soon as possible as a complementary exercise in initial training programs for new power plan workers. This is one of the main TECNATOM's commercial products. A STARMATE session based on a component description including the assembly and disassembly will be added to this initial training program as an added value to their service. This will increase the quality of their product and it will make a distinction between their competitors.

In a second stage, they will try (1) to develop specific training courses based on STARMATE system and (2) to commercialise the product itself as maintenance aid tool. STARMATE can become an attractive offer for providing maintenance services, especially for some type of equipment installed in all nuclear power plants over the world. This feature offers a big number of customers. STARMATE can reduce the costs of training delivery and the cost of maintenance itself. This is the case of the TECNATOM application selected for the STARMATE demonstration. This type of motor-driven valve actuator is a very common component in most of industrial facilities.

As a service company, TECNATOM is interested in finding new commercial markets and partners. TECNATOM intends not only to commercialise the final STARMATE services and products, but also to explore new services in other markets (sectors and/or countries), and to explore the possibility of new commercial relationships.

VI.2.4.EADS

EADS-AIRBUS has several exploitation plans for the AR system as if the goals of the project are achieved, there are great possibilities for its use in the aircraft industry. By the moment in EADS-AIRBUS, some of them could be:

Indicate inexperienced workman the steps to follow:

- Presentation of instructions to follow.
- Explanations by audio and/or video to do clearer the instructions.
- Consult of general database
- Consult of drawings and documentation of equipment.
- Consult of drawings and electrical/hydraulic/assembly schemes.
- Consult of databases of last tests (experiences, detected failures, corrective actions, etc..)

Interaction with the system:

- Reports on-line by voice of test results (success, anomalies, corrective actions, etc)

VI.2.5.DUNE

Integrating a datalink system is a technical issue for DUNE. Although the datalink integrated in the Starmate demonstrators have not a technological interest, Dune will study also the perspectives of a future wireless datalink system. This study will allow Dune to achieve valuable know-how in the field of wireless data transmission, which is going to be one of the most interesting markets in the next future.

VI.2.6.ZGDV

For the ZGDV, the achievements within this project represent an essential step from basic research domains towards product and application oriented research domains. Using the achievements and project results as marketing instruments to demonstrate

research expertise and quality to industrial corporations enables the ZGDV to establish further collaborations with industrial partners with specific focus on application and product oriented research topics.
ZGDV will exploit results of the project for improving its on-going research activity and will disseminate information on results through publications, participation to international conferences and through web publishing.

VII. WORKPLAN AND PROJECT PROGRESS

VII.1. WORKPACKAGE BREAKDOWN

The workpackage breakdown of the project is the following.

VII.1.1. TECHNOLOGY DEVELOPMENT, INTEGRATION AND RESEARCH ON USABILITY

Work-package No	Workpackage title	Leader	Participants
WP1	Project Management	TOSA	
WP2	Specification and preliminary design	CSSI	ZGDV,DUNE,TOSA,TECNATOM,EADS
WP3	System constituents final design development	CSSI	TOSA,DUNE,ZGDV
WP4	Integration	TOSA	DUNE,CSSI,TECNATOM,EADS
WP5	Dissemination and implementation	TOSA	ZGDV,DUNE,CSSI, TECNATOM,EADS
WP6	Assessment & evaluation (unit testing)	TOSA	ZGDV,CSSI,DUNE

VII.1.2. DEMONSTRATION OF USE

Work-package No	Workpackage title	Leader	Participants
WP7	Demonstration of use	TECNATOM	TOSA,EADS

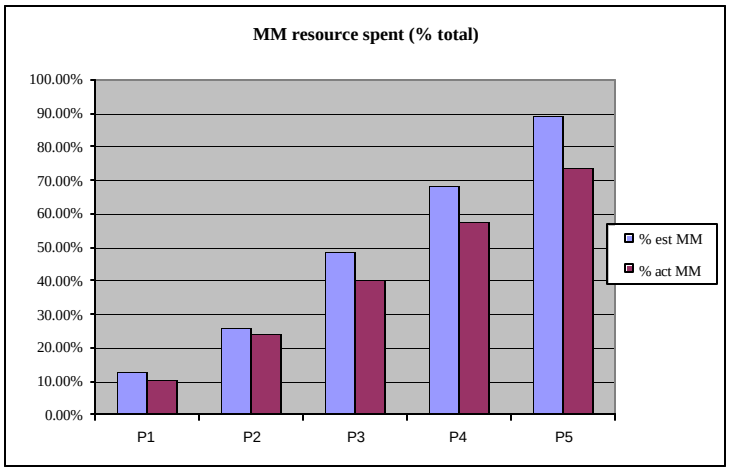
VII.1.3. DETAILS

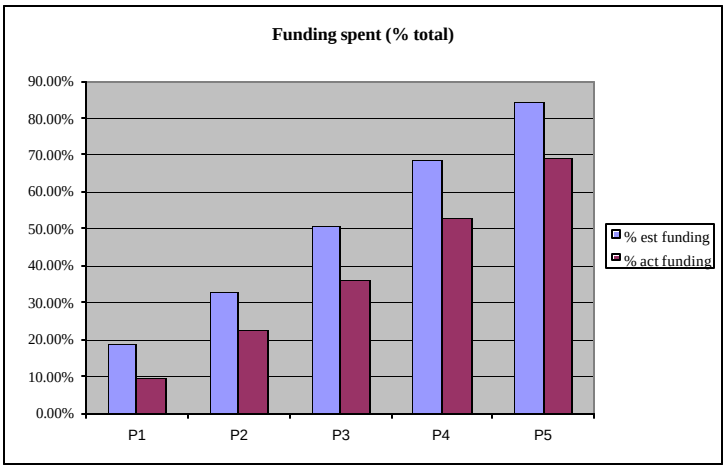
Workpackage / Activity	Participants	Leader
I – Project management		TOSA
1 – General management		TOSA
2 – Work practice management		TOSA
II – Specification and preliminary design	ZGDV,DUNE,TOSA,TECNATOM,EADS	CSSI
1 – General system	CSSI	TOSA
2 – Hardware (UEU + HCU)	TOSA	DUNE

3 – Object tracking system (PAM)	TOSA	ZGDV
4 – Restitution system (RM)		TOSA
5 – Natural User Input(CIM)	TOSA	CSSI
6 – Scenario management (SMM)	TOSA	CSSI
7 – Database management (included into SMM)	CSSI	TOSA
8 – Supervisor (SUP)	TOSA	CSSI
9 –Scenario specification and real case test definition	EADS,TOSA	TECN
III – System constituents development	TOSA,DUNE,ZGDV	CSSI
1 – General system	CSSI	TOSA
2 – Hardware (UEU + HCU)	TOSA	DUNE
3 – Object tracking system (PAM)	TOSA	ZGDV
4 – Restitution system (RM)	ZGDV	TOSA
5 – Natural User Input(CIM)	TOSA	CSSI
6 – Scenario management (SMM)	TOSA	CSSI
7 – Database management (included into SMM)	CSSI	TOSA
8 – Supervisor (SUP)	TOSA	CSSI
IV- Integration	DUNE,CSSI,TECNATOM,EADS	TOSA
1 – System integration	CSSI,TECNATOM,EADS	TOSA
2 – Software integration	TOSA, EADS	CSSI
3 – Hardware integration	TOSA	DUNE
V – Dissemination and implementation	ZGDV,DUNE,CSSI, TECNATOM,EADS	TOSA
1 – Marketing research, users expectations		TOSA
2 – Exploitation planning and market analysis	ZGDV,DUNE,CSSI, TECNATOM,EADS	TOSA
3 – Web site		CSSI
4 – Standard dissemination		ZGDV
VI – Assessment & evaluation (unit testing)	ZGDV,CSSI,DUNE	TOSA
VII- Demonstration of use	TOSA,EADS	TECNATOM
1 – Demonstration	TOSA,EADS	TECN
2 - End-users validation	TECNATOM,EADS	TOSA

VII.2. PROJECT PROGRESS AND EXPENDITURE MONITORING

The progress of the work has been steady throughout the duration of the project and expenditure have been kept under control.





The graphs above show the resources and funding spent compared to what had been estimated for each period (cumulated figures). The expenses are a bit lower than the previsions due to a shift of three months in the starting date of the project and to the leaving of one partner.

VIII.DELIVERABLES

The deliverables that will be produced during this project are recapitulated in the following table.
In grey you will find the deliverables have already been produced.

Del. no.	Deliverable. Name	WP #	Lead participant	Estimate MM	Deliverable Type	Security*	Delivery AC
D1	Project presentation	1	TOSA	0.5	Public report	Pub	T0+24
D2	Web site (main page at T0+3)	5	CSSI	1	Web site	Pub	T0+3/39
D3	First tech specifications and preliminary system design (act 1 to 8)	2	CSSI	0.5	Report	Rest	T0+6
D4	Scenario specs at system level (act 9)	2	TECN	0.5	Report	Rest	T0+6
D5	Dissemination and use plan	5	TOSA	1	Report	Rest	T0+18
D6	Second tech specifications and preliminary system design (act 1 to 8)	2	CSSI	0.5	Report	Rest	T0+11
D7	Third tech specifications and preliminary system design (act 1 to 8)	2	CSSI	0.5	Report	Rest	T0+18
D8	Final scenario specification (act 9)	2	TECN	0.5	Report	Rest	T0+17
D9	First version of market analysis	5	TOSA	1	Report	Rest	T0+24
D10	First version of SW modules (PAM, RM, SMM)	3	CSSI	0.25	SW +report	Rest	T0+18
D11	Report on HCU/UEU integration	4	DUNE	0.5	Report	Rest	T0+24
D12	Report on validation of HCU/UEU usability	6	DUNE	0.25	Report	Rest	T0+24
D13	First version of SUPERVISOR module	3	CSSI	0.5	SW + Report	Rest	T0+18
D14	Validation of CIM and SMM modules	6	CSSI	0.25	Report	Rest	T0+24
D15	Second system integration: SW modules (PAM, RM, SMM+CIM) with HW	4	TOSA/CS	2.0	Prototype	Rest	T0+24
D16	Report on integration and validation of second system integration	6	TOSA/CS	2.0	Report	Rest	T0+24
D17	Second demonstration of the system	7	TEC/TOSA	1	Demo	Rest	T0+24
D18	Second version of market analysis (done by an external consultant)	5	TOSA	1	Report	Rest	T0+33
D19	Third system integration: all SW modules and HW	4	TOSA	0.5	Report + Prototype	Rest	T0+30
D20	Report on integration and validation of third system integration	6	TOSA	0.25	Report	Rest	T0+36
D21	Final system improvements	4	TOSA	0.5	Report + Prototype	Rest	T0+39
D22	Validation of system improvements	7	TOSA	1	Report	Rest	T0+39
D23	Technological implementation plan	5	TOSA	1	Report	Rest	T0+39
D24	Demonstration of the final system	7	TEC/TOSA	1	Demo	Pub	T0+39

(1) Availability: C = confidential, R = restricted, P = public

IX. CO-OPERATION WITHIN THE PROJECT

The co-operation is being intensive during the project. This co-operation is ponctuated by several types of meetings which names and goals are described below.

IX.1. DIFFERENT TYPES OF MEETINGS HELD

Meeting name	Description	Periodicity
Kick off meeting	• Project initialisation meeting. • All aspects of the project discussed • Discussions are more oriented towards strategic aspects than technical details • All partners are represented	Beginning of project
Point meeting	• Opportunity to make a general point on work advance • All aspects of the project discussed • Discussions are more oriented towards general aspects than technical details • All partners are represented	3 months
Cluster meeting	• Allow to solve a specific technical problem. • Precise technical aspects are discussed (specification, design, implementation, optimisation, document review, ...) • Only partners from the different institutions concerned by the problem are represented	Any time
Specific meeting	• Allow to solve a specific technical problem. • Precise technical aspects are discussed (specification, design, implementation, optimisation, document review, ...) • Only partners from the same institutions are present	Any time

IX.2. SUMMARY OF MEETINGS HELD SINCE THE BEGINNING OF THE PROJECT

Meeting type	Number of meeting held					
	Period 1	Period 2	Period 3	Period 4	Period 5	Total
Kick off meeting	1					1
Point meeting	2		1	1	1	4
Cluster meeting	3	6	4	6	4	23
Review Meeting		1	1			2
Specific meeting	5	1			1	7

IX.3. CONCLUSION ON CO-OPERATION

The co-operation is really being very strong between the members of the consortium in this project.

X. SUMMARY OF DISSEMINATION ACTIONS

Promotion and information dissemination has been an active task in Starmate. The list below recapitulates the dissemination actions undergone up to now during the project.

Type of dissemination action	Code						
		Period 1	Period 2	Period 3	Period 4	Period 5	Total
Paper	PAP		1	1	2	4	8
WWW site	WWW	1	1	1	1	1	1
Conferences & workshops	CONF			2	1	1	4
Demonstration / exhibition participation or attendance	DEMO		2	1	3	2	8
Presentation	Pres	4		1	2	2	9

XI. CONCLUSION

Starmate is a project really interesting in a technical and commercial point of view. Its advance is satisfactory. During the project the really strong implication of all the members of the consortium allows to progress significantly in the direction of the common objective.

The main objectives of the coming months is the finalisation of the deployment of the developed system onto other applications, in different places to evaluate the full potential of the system. This as well as the results of the market analysis will be the base of the improvements foreseen for the system.