IST-2001-37652

Hard Real-time CORBA

Title

Project Evaluation Report

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Summary Sheet

IST Project 2001-37652
HRTC
Hard Real-time CORBA

HRTC Project Evaluation Report

Abstract:

This document is deliverable *D6.7 Project Evaluation Report*. It contains the result of the evaluation performed as specified in the Project Evaluation Plan, *i.e.* an evaluation and assessment of the project in terms of expected results.

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1 Introduction

1.1 Description of the document

This is HRTC deliverable *D6.7 Project Evaluation Report.*

It describes the evaluation the HRTC project done in relation to the project expected results.

1.2 Project objectives and scope

The long-term objectives of the project are focused in the advancement of the CORBA technology for the implementation of distributed control systems.

The project has performed activities in domain analysis, testbed implementation and specification fostering inside the OMG.

The concrete expected results that will serve as a basis for the assessment are described in the following section.

1.3 Expected project results

The planned final products of this project are described in the project technical annex as:

1. Know-how in distributed real-time object-oriented control systems.
2. A pluggable real-time ORB protocol prototype.
3. A robot control testbed.
4. A process control testbed.
5. A specification process for CORBA-based control systems.

1.4 Executive Project Assessment

The project work was delayed for several reasons and that has caused a final result that does not fully fulfil the original expectations. This issue clarified, the project activities have reached quite good results in all the five main objectives:

- **Know-how in distributed real-time object-oriented control systems**: Domain analysis, architecting and engineering information collection have been performed. The resulting documents are not definitive but should be considered as a first step in the production of engineering material to be used by control engineering practitioners. These documents will be made public through the CORBA Control Systems Website.

- **A pluggable real-time ORB protocol prototype**: Not one but two pluggable protocols have been developed; one over TTP and another one over switched Ethernet. The TTP protocol demonstrates the possibility of jitter reduction sacrificing flexibility of the application object interfaces. The Ethernet protocol demonstrates that existing off-the-shelf hardware technologies can meet the needs of CORBA control systems when properly managed by software.

- **A robot control testbed**: The RCT implements a CORBA control system of a robot. This is a two level controller with visual servoing based on the Ethernet transport.

- **A process control testbed**: The PCT demonstrates the possibility of using CORBA across the whole plant for process control systems. This system demonstrates true networked control, sensor and actuator wrapping, legacy DCS integration, simulation integration and.

- **A specification process for CORBA-based control systems**: The OMG has chartered a working group in control systems and the specification process for CORBA technologies in control applications has started with the preparation of a white paper and an RFI.

In summary, while not all the expectations have been fulfilled, the final result of the project mostly meets the initial objectives. The results are considered very valuable and they will serve the original purpose of enhancing applicability and perceived value of CORBA technology for industrial control systems.

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2 References

2.1 Project Documents

HRTC Contract (Technical Annex)
Document Number IST37652/001

HRTC Evaluation Plan
Document Number IST37652/005 D6.2

Periodic Progress Reports
Document Number IST37652/005 D6.2

2.2 OMG Documents

Discussion of the Object Management Architecture (OMA) Guide
formal/00-06-41

The Common Object Request Broker: Architecture and Specification
Version 3.0, July 2002
formal/02-06-01

Real-Time CORBA Specification
Version 1.1, August 2002
formal/02-08-02

CORBA Control Systems Request for Information
Version 0.1 September 2003
realtime/03-10-01

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3 Package Evaluation

3.1 WP1 CORBA Control Systems

3.1.1 Domain Engineering

A big amount of work in WPQ has been dedicated to domain engineering for CORBA-based control systems.

D1.1 CCS Domain Analysis analyzed the domain of networked control and object-based control, providing an overall picture of the field that was the basis for the preparation of the rationale for the OMG Control Systems Working Group and the Control Systems Request for Information. All these documents have been well received by the members of the Control Systems Working Group but the real effect and usefulness are still to be determined (during the next months).

D1.2 CCS Domain Architectures proposed a method for domain architecture documentation based on design patterns and included some concrete domain architectures for specific application areas.

D1.3 Engineering Handbook contains information for the engineering of CORBA based control systems. This document has been written considering a reader with background in control engineering and seeking advice on best practices for CORBA use in distributed control systems implementation.

While the consortium has put a big effort in elaboration these documents their real value can only be assessed after a wider dissemination and use of the documents. They are considered just staring points for the planned future activity under the umbrella of the OMG Control Systems Working Group.

This material will be disseminated directly to three main communities and potentially to a wider audience through related journal publications. The three communities targeted in future direct dissemination are:

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- OMG Real-time, Embedded and Specialized Systems Task Force
- IEEE Control Systems Society
- IFAC Technical Committee on Computers and Control

3.1.2 Analysis tools

Two analysis and simulation tools, Jitterbug and TrueTime, have been applied to CORBA-based networked control loops. The tools allow evaluation of how timing variations originating from various sources, *e.g.* network delays, affect control performance.

Using Jitterbug it is possible to analyze how timing parameters in a control loop affect the control performance. The input for the tools is stochastic distributions of sampling periods and input-output latencies. The output is a quadratic performance index. Jitterbug is in itself not limited to the analysis of CORBA-based networked control loops. TrueTime is a simulator that allows the simulation of a real-time network and a real-time kernel in parallel with the simulation of the physical controlled plant. TrueTime can be used both to simulate how different scheduling policies and network protocols affect timing parameters and to simulate how they affect the control performance. However, it should be kept in mind that TrueTime only simulates the timing aspects of the kernel and network. TrueTime does not perform any simulations on the instruction level. The timing resolution of the simulation is also something that the user can control. A very fine-grained simulation takes longer time to simulate than a rough model. It is also important to keep in mind that TrueTime only can be used for comparative simulations, e.g., comparing the performance difference when using different network protocols. TrueTime is not intended for simulation studies with the aim to exactly mimic the true behaviour of a real networked control loop.

Within HRTC TrueTime has been extended in order to allow it to simulate the timing behaviour of CORBA-based control systems. A simple TCP transport protocol was added in order to be able to simulate the timing of IIOP. Support for switched Ethernet was added in order to support the switched Ethernet approach to Hard Real-Time CORBA. Simulation experiments have been performed for both these scenarios. The generated results correspond well to what can be achieved using physical experiments.

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3.2 WP2 Transports

3.2.1 General comments

The protocol plugins developed in the HRTC project are based upon the Open Communications Interface (OCI). The OCI interface was one of the first proposals presented to the OMG for the use of pluggable ORB transports that has recently lost its relevance by the adoption of the Extensible Transport Framework (ETF). Whereas this could be considered an inconvenience, it is not. OCI is available in a significant number of commercial ORBs which might be adapted to the HRTC protocol specification. Further, the concepts handled by the ETF are exactly the same as those of the OCI. The effort of changing the ORB interfaces from OCI to ETF can be considered as moderate. In HRTC we have taken advantage of existing OCI implementations without having to implement what looks like a revamp of OCI (the ETF).

For hard real-time it is important to know when things happen. The HRTC Protocol Specification provides a time-stamping feature that has been implemented in the ORB (following reviewers recommendations) so applications can gain knowledge of the order of events/time progression.

Although the HRTC Protocol Specification deals with the transport level of the distributed system, the issue of system synchronisation from the CORBA point of view has been considered but not dealt with as it falls outside the scope of the project. However, an strategy based on the transport has been used for system synchronisation. In the case of TTP, a node knows that certain data will be available at pre-specified intervals in time so no interfaces for global system synchronisation are required. In the case of RT-Ethernet, a RT Layer in the transport between the IP and ethernet layers is responsible of guaranteeing that the network schedule holds and of traffic control for worst-case scheduling. As with TTP, no additional synchronisation interfaces are needed.

3.2.2 Evaluation of the OCI transports

The transmission of a message that is sent over a communication channel can be subdivided in several steps with individual delays. The *sender delay* denotes the time between the request to send the message and when the operating system of the sending node decides to perform this operation. After the *access delay* the channel is free and the first bit can be put on the wire. When the *transmission delay* has elapsed the last bit of the message has been received by the receiver node. After the *receiver delay* the message has been delivered to the application by the operating system.

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While the access delay and the transmission delay depend on the communication system (and maybe the traffic pattern of other nodes) the sender delay and the receiver delay depend on scheduling decisions within the (sender or receiver) node.

The end-to-end delay of a CORBA request (or any other message) that is sent over a communication channel can be described as the sum of sender delay, network latency, and receiver delay. In order to guarantee an upper bound for the end-to-end delay it would be necessary to provide upper bounds for all four of these delays. While this already has been done for the access delay and the receiver delay further research is required for coping with the sender delay and the receiver delay which is subject of scheduling decisions of the operating system.

3.2.3 TTP/C Prototype

For evaluation a cluster consisting of four nodes connected with a TTP/C network has been set up. The central guardian has been replaced by a regular Ethernet hub. Although this means that the possibility of some special failure modes, e.g., SOS-failures, has been neglected it is possible to reintroduce it later without any further changes since the central guardian is transparent for the nodes if it is necessary to consider these failure modes.

Since this prototype transport is especially designed for transmission of periodic control messages as oneway invocations and thus another way is necessary for detecting failed nodes. Thus this transport makes available the TTP/C membership vector which allows detecting failed nodes with short error-detection latency. Further it benefits from the fault tolerant global time-base that is maintained by the communication controller and provides a precision which is typically below 1 µs. This global time base is available in each node and is used for timestamping of significant event like the arrival of a measurement.

In order to have a situation comparable to CORBA a test-program has been running in user-mode and accessed the kernel-functions in the same way as in our prototype (TDMA round length of 3.2 ms and an available bandwidth of 640 Bytes per Node and TDMA round). Several tests have indicated that TTPIOP is a viable way towards hard real-time CORBA. For about 90% of the measurements the jitter has been as expected (i.e., the same as measured for the underlying transport: about 1 µs). In a few of the remaining 10% of the measurements a considerable jitter of several milliseconds has been noticed. This is because the ORB is running in user-mode and thus is subject of scheduling decisions.

The measured jitter in the setup has been independent from the load on the non-real-time channel. Compared to IIOP – especially for high load scenarios – advantages regarding the jitter are eminent.

3.2.4 Real-Time Ethernet Prototype

A testbed has been setup involving four nodes: one sensor (resolver) node using the ETRAX hardware, one actuator (motor) node using ETRAX, one controller node based on PowerPC and one camera node based on Intel. The testbed allows comparisons between conventional IIOP-based transport mechanisms and transports based on the new switched Ethernet approach using ThrottleNet at the link layer. Several tests and experiments have been performed.

All the tests and experiments performed point in the direction that the proposed switched Ethernet approach is a useful HRT-CORBA transport mechanism for control applications with requirements on high performance and guaranteed upper bounds on network latencies, but where a latency jitter is acceptable.

The network latency (not end-to-end latency, since a unicast approach is used) is considerably smaller with the HRT transport than with the IIOP transport, in particular in the presence of disturbing network traffic. The proposed approach is also close in spirit to the standard CORBA client-server communication model.

3.2.5 Conclusion

These two protocols address various aspects of the problems occurring frequently in control systems and allow to explore different approaches for solving them:

Thus the TTPIOP, which uses a broadcast channel that is accessed according to an a priori known TDMA schedule for communication between the nodes, is based on the periodic transmission of state messages as nonblocking CORBA oneway invocations while the Real-Time Ethernet approach provides independent communication channels for incoming and outgoing messages for transmission of answers in bidirectional invocations. The TTPIOP is based on a communication controller that supports a fault-tolerant timebase with a very small jitter while the Real-Time Ethernet approach uses “components of the shelf” and a global time

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has to be realized in software and thus a greater jitter must be considered. Another aspect is the integration of real-time traffic with non-real-time traffic (e.g., for configuration of the system). While the TTPIOP approach uses dedicated parts of the slots in the TDMA round for each application while the Real-Time Ethernet uses a "Throttle" in order to limit the available bandwidth for each application.

An analysis comparing both implementations could not be performed since the exact figures regarding the Real-Time Ethernet prototype have been available too late.

It has also been demonstrated that CORBA introduces relevant delays because of the sender delay and of the receiver delay. Fixing this problem requires either to run the relevant parts of the ORB in kernel-mode or find mechanisms to bind the latencies in user-mode.

3.3 WP3 Robot Control Testbed

According to *D6.2, Evaluation Plan*, the evaluation procedure for WP3 states that the testbed is to be evaluated by a review investigating the following three questions.

1. Experiments that have been performed and documented; Have the concrete objectives been met in terms of experimental possibilities.
2. Has the RCT contributed to any conclusions concerning useful or deficient techniques within the CORBA domain, applications, or control?
3. Is the testbed useful for demonstrations of CORBA features and limitations?

Availability of the simulation and soft RT parts in a virtual setting, e.g. to have a transportable testbed for demonstrations, is an extra plus.

3.3.1 Evaluation

Question 1

Yes, the desired experiments have been performed. However, at the moment of this writing, the documentation in terms of deliverables[1] is not ready. Since there are no technical difficulties remaining, and assuming delivery of documentation in the very near future, the final issue is the

[1] Deliverables D3.4, D3.5, D3.6 and D3.7.

experimental possibilities. The experiments as specified within the project are possible to carry out, implying a positive evaluation. Our additional aim (mentioned but not promised) of running the outer control loop including two cameras for stereo vision was, however, not possible to accomplish: Our porting of the networking to the new Axis ETRAX processors were more time consuming than expected, and the delivery of the new cameras built with such processors was delayed from Axis Communications. Due to the encouraging results of the HRTC platform that work will continue anyway after the project.

Question 2

For engineers with a background in control, the RCT experiments have confirmed the expected robot motion problems when using the soft real-time protocols with CORBA or RT CORBA, and also confirmed the appropriateness of the hard real-time protocol (ThrottleNet in our case) for object interaction in hard real time. For the software engineering community, the results should be illustrative and important for the understanding of timing and delays in distributed systems.

Question 3

Yes. The features in terms of IDLs for control components, and the like, is quite useful. Concerning limitations, the main problem we have experienced is the rather complex engineering required to get an ORB with a pluggable transport running on new types of hardware. To reduce this problem, using minimum CORBA as the basis for HRT CORBA could be a suitable approach. Another motivation for that approach is that the rather small ETRAX nodes provide quite limited resources in terms of memory and CPU speed, as clearly illustrated by the RCT.

The additionally desired simulation of the soft RT parts has been conducted, except for the actual catching of moving/flying objects in the virtual world. However, the required tailoring of the graphics rendering to emulate the real-time aspects of visual feedback involved low-level OpenGL programming. The implementation is not sufficiently portable nor robust nor documented for a release. Instead, it will be reworked after the finalization of the current project, and made available via Java classes and native methods. Hence, the extra plus we aimed for has not been accomplished.

3.4 WP4 Process Control Testbed

The PCT testbed evaluation criteria depends on the concrete deliverable, but as a whole, the valuable part consists on an analysis of the experiments done because this is what enable us *to identify new CORBA requirements for distributed control systems.*

3.4.1 Ethernet experiments

Experiment 4.1a: CCS Ethernet loop

The experiments made with the Hub and with the Switch show that the timing properties of the control loop are sufficient for process control, where reaction times go from 5-10 milliseconds in the field level to 100ms in the control network level. The loop cycle of the experiment is around 10 ms in both cases (hub and switch). The overhead imposed by using the CORBA middleware is low and non significant.

In this experiment the actuator and the sensor have been wrapped with the CORBA layer through the use of a PC. In the actual process industry CORBA should go embedded in the instrument itself, leveraging the current trend towards digital, “intelligent” devices.

This means that the footprint should be quite small as the memory of these devices is low.

CORBA calls should be non-blocking (`oneway`) in order to avoid additional latency and to get stalled when an instrument fails. (It is better to use the “last measurement” until the device is restored or the back up unit is online).

CORBA implementation should allow that a client be alive even when the server goes down, and to automatically detect when the server goes up again and connect to it.

Experiment 4.2: Legacy systems integration

The possibility and characteristics of the integration of legacy systems in CCS are fundamentally determined by the facilities provided by vendors of that system, not CORBA. For control purposes, in the case of the TPS the fastest access to the controller node (HPM) is achieved via the Serial Interface (SI). This interface has several limitations in temporal behaviour and capacity. For read operations:

- 80 SI connections at 1 second scan period
- 40 SI connections at ½ second scan period
- 20 SI connections at ¼ second scan period

For write requests, the number of consecutive write data requests is limited to 16, after which, one array point read request is issued. Further, constant writes to the serial interface (for example, a logic output) can overload the system and degrade performance.

In conclusion, the integration of the TPS in a CCS system has been demonstrated as possible but it is very constrained in capacity and scan period. Additionally, there is uncertainty in the temporal behaviour. This allows some degree of integration in typical process plants but is not the ideal case.

Experiment 4.5: Interaction between simulation and control

This is an off-line experiment. The integration of ABACUSS II and the HMI and the interaction with the actual regulator has been easy using CORBA. This was possible due to the availability of the simulator as a library.

The CORBA object wrapped the ABACUSS simulator using its native interface and linked to the library to obtain the final CORBA simulation object. The use with commercial simulators is not so straightforward. Although the Cape Open initiative (for open simulation using CORBA or COM), which enables the use of components of different simulator, could be a way to achieve a more wide and generic integration between CORBA objects and COTS simulators.

The use of real time simulation online needs to extend CORBA to handle the notion of time to interact with the simulator. One approach is to use the standard RTI (HLA) for distributed simulation and extend it to real time.

Experiment 4.6: Intensive data traffic

The transmissions size in the field level are traditionally small (field networks communicate at a rate of 32kb/s) but the use of digital devices will increase the size significantly (although being small). The control level uses high rate transmission networks (10/100Mb/s).

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The experiments performed on the Hub network show that the loop performance degrades under a heavy load on the network. The single collision domain makes that the latency increases as well as its jitter.

The switched Ethernet can cope with the heavy load of the network but there is a limit which is set by the capacity of the switch buffers. A Switched Ethernet could be used then for process control without further consideration. But although the load in the process control network layers is usually not very high, it can eventually go beyond the switch capacity during certain transient conditions. As the process control layer has to be predictable a limit has to be set, and at least a worst case scenario analysis is needed.

The use of CORBA with a standard widely used network like Ethernet is appealing for the process control domain as the control layers can be flattened and homogenised. Costs —both first installation and maintenance— can be reduced and real-time plant information can be made be available to any node in the system. This obviously poses a security problem (and possible network degradation) so it is critical to control the information flow between the control and the business layer.

Experiment 4.7: Concurrent access

The experiments performed on the Hub network show a control loop performance degradation. Latency times and its variability are increased. The switched Ethernet experiment is also affected by the concurrency access, although results are still good for process control.

It is clear that a priority policy is needed for process (and any other) real-time complex control systems. Priorities tend to grow as going down to regulatory and safety control loops: The regulator should have the highest priority accessing the pH value. But for large and complex control systems where predictability (or at least a bounded worst case) is a must it is advisable to use deadlines instead of priorities (you have to know when —in the worst case— something is going to happen). This is something that has to be implemented in CORBA.

CORBA has proved to handle very well requests at a very high rate as all the elements (specially the pH sensor) performed quite well in these experiments.

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3.4.2 TTP Experiments

Experiment 4.1.b: CCS TTP loop
Experiment 4.3: Sequence of events generation
Experiment 4.8: Merging networks

The PCT platform and experiments have been re-designed and ported to the TTP MonitoringNode platform. Some cases running under over the TTP network but with the conventional IOP protocol were programmed and tested.
The real HRT testbed experiments have not been done yet as the implementation of the TTP protocol (TTPIOP) that was used for in-house tests in Vienna and integrated with the ICa ORB was not flexible enough to support the PCT. Work is being done at the time of this writing to solve last issues.

In WP2 there are some preliminary experiments based on earlier versions of the TTPIOP implementation.

The results of the experiments will be made available through the project website in the near future.

Besides the lack of the real testbed experiments some conclusions can be stated about using TTP for process control systems. It has the advantage of being more predictable which is very important for any control system but:

- It is not flexible enough; everything has to be known in advance so a proper design can be done and schedules generated with the TTTech off-line tools. This can be useful for "not changing" systems —like a car or an airplane— but it is not for process control where the control configuration can change (due to many reasons, new control loop configuration, revamping of the process …).
- It is oriented only to time triggered events. The event time has to be known in advance. In process control state asynchronous events happen and have to be managed.
- The way it operates through a broadcast of the information to all the nodes is opposed to the CORBA client/server philosophy.

The first two drawbacks could be overcome reserving (empty) slots for new nodes and checking at every time slot if a state event has happened. This solves (in part) the problem but is not how TTP has been designed to work.

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Finally, a typical process control system has two important elements that don't need hard real time requirements: the Human Machine Interface and the Historical Module (or Database). This means that the TTP network should be accessed from the Ethernet network. This poses the problem of a CORBA gateway communicating two different protocols on the TTTech Node. Other problems are related with the low available memory of the nodes (as all the variables are broadcasted this can be a problem in a network with thousands of signals), or with how "non control" functions that are available in digital instruments can be handled on the TTP network; functions as device information for maintenance analysis, on-line software changes, etc.

3.4.3 Overall evaluation and conclusions of the Process Control Testbed

CORBA is a potential element to incorporate to process control systems. Many features make it really attractive but there are features missing as deadlines (better than priorities) for requests. The overhead imposed is not significant for the loop timing properties, it can cope with concurrent requests and it works well with multiple objects (around two hundred objects and 6000 thousand signals were alive in the intensive traffic experiment). It is more than just an alternative to OPC for process control systems.

A CORBA feature that was very useful in the implementation and testing process was location transparency. This is extremely valuable as enables some dynamism in the allocation of objects to nodes.

Fault tolerance in networks and nodes is a must in process control systems. A redundant network and some components are the norm in current process control. Due to the additional complexity, and limitations of the platforms they have not been implemented in the PCT.

Another issue not explored (due to the scope of the project) is control system configuration. CORBA could allow the automatic detection of new nodes in the control network. This can be seen as something good or convenient, but it is intrinsically dangerous, since it can compromise the operation of the system. The classic approach in process control systems implies a configuration step where a rigid definition of the nodes and connections are established. Maybe, some degrees of freedom or convenience provided by CORBA are welcome, but control systems in plants are unlikely to not have a well defined configuration. This means that specific components (like configuration utilities) and specifications (like the ones that enforce configuration) would have to be developed, or even better, become a standard, if CCS is to be used by industry. It is important to distinguish between the reconfiguration needed in process control (when a new configuration –nodes- is needed it has to be well-defined) and the redesign of the control system that is needed if TTP is used.

Many of those CCS components and specifications should be oriented to safety: Safe operation of process plants is essential because they process large quantities of toxic or explosive material and accidents can lead to important losses in terms of human life, property and the environment.

One of the aspects is error management in a complex software system. The classic approach has been relatively simple systems with reliable connections. The potential flexibility of CCS is a risk that should be minimized, perhaps leading to some loss of that flexibility. Another necessity is the provision of diagnostic tools for CCS.

On the other hand, real-time is not very exigent in most of the process control applications. Lag times in instruments and equipments are in the order of, at last, hundreds of milliseconds and the networks used up to day are much less than what we have in Ethernet.

So, real time Ethernet is the best solution (of the two alternatives considered) to use with CORBA in process control systems as it can provide a predictable but more flexible environment and the use of a widely used technology as it is Ethernet.

3.5 WP5 Dissemination

3.5.1 OMG Process

The overall success criterion for this work package is the existence of a specification process inside the OMG to deal with HRTC issues. WP5 has been subject to external factors as those related to the OMG specifications process and others as the USA-Iraq war and the SARS illness that the Consortium could not fully control. This has resulted in two meeting being lost but the Consortium has managed to establish a Control Systems Working Group inside the OMG, to prepare the charter of the WG and establish its rationale in a white paper.

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A last symptom of success in WP5 is the preparation of a RFI that is foreseen to be presented in next OMG London meeting. Regarding the most important objective of WP5, we must consider that the work and results inside WP5 has been completely successful.

The RFI Draft has been submitted to the OMG Control Systems Working Group for discussion (document realtime/2003-10-01) and some comments have been received regarding inputs to be considered for this work and specification work that is correlated.

This is what E. Douglas Jensen from Mitre wrote about the document:

> I think this is an extraordinary and wonderful document.
> I happen not to entirely have the same perspective as
> the authors on real-time CORBA and real-time in general
> as regards control systems (at least the large complex
> type we build for military battle management and weapons).
> But I am very impressed with the RFI anyway.

Our work inside OMG has been very favourably received and we expect to continue the real-time control systems specification processes inside it.

3.5.2 Secondary goals

Regarding secondary goals of the WP and following the reviewers recommendations (1st Project Technical Verification) there has also been success. Specifically, the number of companies contacted for interview in order to learn information regarding HRTC systems was increased by ten times. From these, there was a 10 per cent response which was acknowledged by the review team as a good result (the usual response statistic for this type of task is 5%). This result has been a consequence of the persistence of the WP5 team in getting responses from interviewees.

Taking all the WP5 tasks into consideration we can consider WP5 as completely successful.

3.6 WP6 Management

As the Project Evaluation Plan specifies, success in this workpackage will be demonstrated by the efficient use of the resources to achieve success in each workpackage as stated in previous sections.

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The evaluation will be obviously based in the level of success in each of the previous workpackages. As was previously explained, the level of achievement in each workpackage was different.

Worpackage 1 (CORBA Control Systems) was relatively independent and achieved more results than planned initially without much overspending. Apart from the documentary results (D1.1 Domain Analysis, D1.2 Domain Architectures and D1.3 Engineering Handbook) additional work has been done in relation with the use of analysis tools for evaluation of CORBA-based control loops.

Workpackage 2 (Transports) was at the same time successful and failing. It provided two transports instead of one (Lund University contributed with one of the transports beyond what was originally planned). But both transports were delayed beyond what was reasonable and produced delays in dependent work in WP3 and WP4 that were unable to complete the tests over the new transports.

Worpackage 3 (Robot Control Testbed) spent most of the effort migrating available software to new platforms (controller code from Lund, ORB code from SCI). The working system was delayed beyond the end of the project.

Workpackage 4 (Process control testbed) managed to have the testbed running on conventional CORBA but spent too much effort in implementing over changing software platforms (Linux/RTAI). Tests were done and experimental results gathered. Tests over the new more predictable TTPIOP transport were not possible to be done due to the delay problem and they are being performed these days.

Workpackage 5 (Dissemination) was successful and is still active (alive after death, we would say). The OMG Control Systems Working Group is fostering specifications in the field of distributed control systems, having a RFI under way. Publications have also been done at some control conferences and journal papers are in process. A marketing analysis was done that gathered information about the potential use of Real-time CORBA technology by systems implementers and integrators in the control field.

Taking all this into account, we can say that WP6 (Management) was successful (WP1, WP5), relatively successful (WP4) and less successful (WP2, WP3).

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4 Annex: Project Documents

Entries marked with * were given to the review team in addition to deliverables.

Number	Title	Main Author	Deliverable
001	HRTC Contract	HRTC Consortium	
002	Barcelona Meeting Minutes	Ricardo Sanz	
003	Dissemination Plan	Ricardo Sanz	D5.1
004	Project Management Manual	Ricardo Sanz	D6.1
005	Evaluation Plan	Ricardo Sanz	D6.2
006	PCT Requirements Specification	Manuel Rodriguez	D4.1
007	Reading List	Ricardo Sanz	
008	Long Report Template	Ricardo Sanz	
009	Short Report Template	Ricardo Sanz	
010	Presentation Template	Ricardo Sanz	
011	Vienna Meeting Minutes	Ricardo Sanz	
012	Vienna Meeting Agenda	Thomas Losert	
013	Meeting Objectives and Project Status	Ricardo Sanz	
014	CORBA Control Systems	Ricardo Sanz	
015	Real-time CORBA	Miguel Segarra	
016	CORBA Pluggable Transports	Miguel Segarra	
017	Networked Control Systems	Karl-Erik Årzén	
018	Scheduled Switched Ethernet	Anders Blomdell	
019	Introduction to TTA	Thomas Losert	
020	OMG Smart Sensors Specification	Thomas Losert	
021	TTTech Demonstration	Ralf Schlatterberg	
022	Robot Control Testbed	Klas Nilsson	
023	Process Control Testbed	Manuel Rodriguez	
024	Meeting Closing Issues	Ricardo Sanz	
025	Advance Payment	Ricardo Sanz	
026	HRTC Flyer	Ricardo Sanz	D5.3.1
027	Presentation Template (Light Side)	Ricardo Sanz	
028	HW/SW Platforms	Thomas Losert	
029	HRTC Overview - OMG Sep'03	Ricardo Sanz	D5.2.1
030	Quarterly Report M3	Ricardo Sanz	D6.3
031	OMG Helsinki Technical Meeting Report	Ricardo Sanz	
032	Hard Real Time CORBA - Project IST 37652	Thomas Losert	D5.2.2
033	Control Systems WG – Towards HRTCORBA	Ricardo Sanz	D5.2.3
034	OMG Nov'03 Tecnical Meeting Report	Ricardo Sanz	
035	OMG CSWG Charter	Ricardo Sanz	D5.2.4

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036	Protocols for Real-time Control	Thomas Losert	D2.1
037	Review Meeting Agenda	Ricardo Sanz	
038	PCT Design	Santos Galán	D4.2
039	PCT Procurement	Santos Galán	D4.3
040	CORBA for Control Systems White Paper	Ricardo Sanz	
041	HRTC for Chemical Control Systems	Santos Galán	D5.3.3
042	Periodic Report M6	Ricardo Sanz	D6.4
043	RCT Requirements Specification	Klas Nilsson	D3.1
044	RCT Design	Klas Nilsson	D3.2
045	Paper for ADCHEM 2003	Santos Galán	D5.3.2
046	RCT Procurement	Klas Nilsson	
047	First Review Shipment	Ricardo Sanz	
048	HRT Protocol Specification	Miguel Segarra	D2.2
049	Draft Exploitation and Use Plan	Miguel Segarra	
050	CCS Domain Analysis	Karl-Erik Årzén	D1.1
051	Questionnaire	Carlos Baeza	
052	Minutes of the Brussels PM	Santos Galán	
053	Minutes of the 6M Review	Santos Galán	
054	Brief Questionnaire	Miguel Segarra	
055	OMG TC Jan. 2003 Meeting Report	Ricardo Sanz	
056	Madrid Meeting Minutes	Santos Galán	
057	TrueTime and Jitterbug	Anton Cervin	*
058	ICa Install	Rafael Chinchilla	
059	HRTC Consortium Agreement	Sibylle Kuster	
060	CCS Domain Architectures	Santos Galán	D1.2
061	Minutes of the 4th Technical Meeting	Ricardo Sanz	
062	Short Term Planning	Ricardo Sanz	
063	CSWG Meeting	Ricardo Sanz	D5.2.5
064	CSWG Rationale	Ricardo Sanz	D5.2.6
065	CSWG Control Systems White Paper	Thomas Losert	D5.2.7
066	RT Ethernet transport definition	Anders Blomdell	*
067	TTP transport definition	Thomas Losert	*
068	PCT Testing	Manuel Rodriguez	D4.6
069	PCT Documentation	Manuel Rodriguez	D4.7
070	RTE-DOC HRTC Poster	Ricardo Sanz	D5.2.8
071	RTE-DOC CORBA in the TTA	Hermann Kopetz	D5.2.9
072	CCS Engineering Handbook	Ricardo Sanz	D1.3
073	Second Review Meeting Agenda	Ricardo Sanz	
074	CSWG RFI	Ricardo Sanz	D5.2.10
075	Non HRT PCT Implementation	Manuel Rodriguez	D4.4
076	HRT PCT Implementation	Manuel Rodriguez	D4.5
077	Quarterly Report M9	Ricardo Sanz	D6.5
078	Non HRT RCT Implementation	Klas Nilsson	D3.4
079	HRT RCT Implementation	Klas Nilsson	D3.5
080	Periodic Report M12	Ricardo Sanz	D6.6
081	HRT Protocol	Miguel Segarra	D2.3
082	HRT CORBA Market Study	Miguel Segarra	*
083	Web Page	Miguel Segarra	D5.4
084	First payment	Ricardo Sanz	
085	Exploitation and Use Plan	Miguel Segarra	D5.6

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086	Second Review Deliverables	Ricardo Sanz	
087	Second Review Minutes	Ricardo Sanz	
088	Technology Implementation Plan	Miguel Segarra	
089	RCT Testing	Klas Nilsson	D3.6
090	RCT Documentation	Klas Nilsson	D3.7
091	Project Evaluation Report	Ricardo Sanz	D6.7
092	Periodic Report M15	Ricardo Sanz	D6.9
093	Final Report	Ricardo Sanz	D6.8

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