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Apêndice A: Entrevistas

Neste Apêndice, relatamos as entrevistas que foram realizadas com os usuários-chave quando do levantamento dos requisitos do sistema.

No dia 13/10/2004, reuni-me com o engenheiro Álvaro Maia, Gerente dos Métodos Científicos do Centro de Pesquisas e Desenvolvimento da Petrobras (CENPES), abordando os acidentes na área de óleo e gás:

- os maiores foram o do Exxon Valdez (4 a 8 bilhões de dólares) e o do Piper Alpha;
- Álvaro falou que o pior é o lucro cessante: 150.000 barris por dia por 3 anos de uma P-40 são US$ 3 bilhões (com um cálculo bem conservador considerando US$ 20 o barril; hoje, ele já passa dos US$ 40), fora US$ 700 milhões do empreendimento.

Em 15/10/2004, o Prof. Terrence Fernando da University of Salford teve uma reunião com o engenheiro Álvaro Maia, discutindo detalhes sobre a operação de plataformas e sobre as situações de emergência:

- as plataformas da Bacia de Campos pertencem à Unidade de Negócios do Rio (UN-Rio);
- os dados sobre as plataformas ficam armazenados no sistema GIEN;
- o controle de lastro e estabilidade da plataforma é feito utilizando-se o software SSTAB;
- em situações de emergência, uma equipe típica é constituída de três especialistas de hidrodinâmica, três especialistas de análise de *risers* e 10 especialistas de análise de estabilidade;
- o sistema InfoPAE possui os procedimentos a serem seguidos em casos de emergência;
- a esposa do Álvaro Maia fez uma tese de doutorado sobre comportamentos em empresas em situações de emergência (Costa, 2004).

Ainda em 15/10/2004, o Prof. Terrence e eu nos reunimos com o engenheiro Isaias Masetti, também do CENPES, para discutirmos requisitos do sistema:

- Masetti deseja que o sistema se pareça com um jogo de computador;
- deve tratar de estabilidade e hidrodinâmica;
- no mínimo deve contemplar:
  - SSTAB + DYNASIM (código aberto) + dinâmica;
  - para cada inclinação no tempo:
    - análise hidrodinâmica;
    - forças;
    - cada passo no tempo.

  Não seria para um caso de emergência (isto é feito pelo SSTAB);
- Masetti falou sobre o Tanque de Provas Numérico (TPN) ou *Numerical Offshore Tank* (NOT);
- falou também sobre o *Mesh Generator* (MG);
- falou ainda sobre o *Web Analysis*, desenvolvido por uma parceria entre a UFAL e a USP:
  - eles programariam e eu elaboraria o conceito (seria o arquiteto do sistema);
  - envolveria realidade virtual + análise hidrodinâmica + análise de linhas;
  - seria para *benchmark* com modelos de pequena escala.

  Seriam elaborados modelos para verificar o sistema;
- SSTAB -> WAMIT (do MIT) -> TPN: não é tempo real;
- TPN = DYNASIM + WAMIT (coeficientes de forças hidrodinâmicas).

  Pelo menos, deveria ser feita a integração do SSTAB com estes sistemas;
- a idéia seria fazer uma grande cooperação envolvendo a UFAL (análise de linhas), a USP (DYNASIM + WAMIT + realidade virtual), a PUC (MG + SSTAB) e também a University of Salford:
  - a análise de linhas é a mais pesada (as outras demoram apenas 5 minutos);
  - tempo real;

- mudanças repentinas, linhas danificadas;
- cada sistema foi desenvolvido no Mestrado de alguém:
  - DPS: *Dynamically Positioning System* (ao invés de sistema de movimento);
  - WAMIT: do engenheiro Donato, do CENPES;
- o sonho do Masetti é fazer tudo via Web, sem a necessidade de uma grande estação de trabalho;

- alta tecnologia para o futuro seria um grande aglomerado de computadores: verificar os requisitos e treinamento;
- o sistema é distribuído: temos que ver as interfaces com as pessoas;
- SSTAB + DYNASIM + WAMIT integrados:
  - primeiro passo: colocá-los juntos;
  - propriedades de estabilidade:
    - quase-estática (passo a passo);
    - depois disso, dinâmica (ex.: *Particle Method System* – PMS);
- se o sistema for um sucesso, será passado para o GIEN e todo mundo o utilizará:
  - o melhor seria fazer um pré-processador para importar os dados de entrada reais (faríamos uma *shell* sem provocar nenhum ruído):
    - eles podem assumir o novo formato no futuro;
    - sistema especializado para danos.

Em 31/01/2005, o Prof. Terrence e eu apresentamos a Proposta de Tese ao engenheiro Álvaro Maia, que, após ler detalhadamente a Proposta, nos deu o seguinte retorno:

- considerou a Proposta muito bem organizada e disse nunca ter visto uma Proposta tão bem descrita;
- aconselhou investigar os Sistemas de Tratamento de Crises existentes;

- no acidente da P-34, teve que re-executar todas as simulações de novo para preparar o relatório; agora tem todas as simulações armazenadas no sistema INFOPAE;
- depois do acidente da P-36, o sistema GIEN da Petrobras passou a armazenar todos os modelos;
- disse para se prever até 10 a 15 pessoas acessando o mesmo modelo, ao se fazer simulações via o INFOPAED (INFOPAE Dinâmico);
- disse que a tese deve enfatizar o aspecto de visualização.

  O Prof. Terrence disse que as pessoas poderão fazer suas próprias simulações e mostrar seus resultados;
- disse que o principal objetivo é mostrar os resultados via o INFOPAED, que utiliza o banco de dados do INFOPAE com simulação em tempo real (todos os modelos seriam executados por meio do INFOPAED);
- fez uma correção na Proposta: a decisão de alto nível não está na Sede da empresa, mas sim na Unidade Operacional;
- disse para reduzir o escopo da tese, fazendo apenas uma definição em nível mais amplo e se concentrando na parte técnica, se possível com um exemplo prático (um programa com visualização ou um algoritmo);
- O Prof. Terrence disse que a tese definiria um terceiro paradigma (após os acidentes da P-36 e da P-34) para tratamento de emergências como seu resultado e também que o desenvolvimento não partiria do zero, aproveitando-se a tecnologia já disponível.

Em 02/02/2005, o Prof. Terrence e eu conversamos com o engenheiro Luiz Cristovão Coelho do Tecgraf/PUC-Rio, que participou das operações de salvamento tanto da P-34 quanto da P-36:

- a *task force* da P-36 estava baseada em Macaé e a da P-34 na UN-Rio;
- o modelo de estabilidade da P-36 foi feito em dois dias com mais volumes e baseado em modelo de empresa terceirizada;

- o modelo de estabilidade da P-34 foi feito em duas horas com uns 10 ou 15 volumes;
- não havia como salvar a P-36 sem estabilidade, mesmo com mergulhadores.

Em 04/02/2005, o Prof. Terrence e eu fomos recebidos pela Taciana Melcop no Tecgraf 2 da PUC-Rio, que nos falou sobre o CSGRID (o *framework* utilizado pelo INFOPAED):

- os programas são acionados em algum servidor e lêem e escrevem na área central de dados, que é protegida;
- vários simuladores do Álvaro Maia estão nas listas e podem ser acionados (alguns podem ser executados em aglomerados de computadores): ANFLEX, ANPEC, SSTAB, WAMIT, etc;
- SSTAB hoje só pode ser executado como programa externo:
    - carrega o dado da área central em disco local;
    - copia do disco local para a memória e apaga o disco local;
    - no final da simulação, copia da memória para o disco local;
    - finalmente, copia do disco local para a área central e apaga do disco local.

Em 26/09/2005, reuni-me com o engenheiro Mauro Costa Oliveira no CENPES, discutindo sobre o uso integrado dos simuladores SSTAB, WAMIT e DYNASIM em situações de emergência. O engenheiro Mauro disse que teria interesse em testar a arquitetura sendo proposta também em trabalhos de rotina.

Em 05/10/2005, fiz a apresentação sobre a tese para o Gerente de Pesquisa, Engenharia e Corporativo da Tecnologia da Informação da Petrobras (TI/TI-PEC), Roberto Murilo, na presença dos orientadores Prof. Terrence Fernando e Prof. Alberto Raposo. O retorno dado pelo Gerente Roberto Murilo foi bastante positivo, com ele se mostrando interessado no uso da arquitetura proposta também em outras situações de emergência, como por exemplo em refinarias.

Em 06/12/2005, reuni-me com o engenheiro Mauro Costa Oliveira no CENPES, discutindo formas de se acionar automaticamente o simulador WAMIT a partir da obtenção do resultado do simulador SSTAB.

Apêndice B: Artigos Publicados

Reproduzimos no presente Apêndice os quatro artigos que já foram elaborados a respeito deste trabalho e o resumo da palestra proferida durante uma oficina internacional no Reino Unido.

Os artigos serão apresentados na ordem seguinte:

1. *A Multiple-Perspective Architecture for CSCW Applications*.

   Co-autores: Alberto Raposo, Terrence Fernando e Marcelo Gattass.

   Este artigo será apresentado durante a *7th International Conference on the Design of Cooperative Systems* (COOP'06), a ser realizada em Provence, França, de 9 a 12 de maio de 2006.

2. *Configuring a Collaborative Virtual Workspace for Disaster Management of Oil & Gas Offshore Structures*.

   Co-autores: Alberto Raposo, Terrence Fernando, Marcelo Gattass e Börje Karlsson.

   Este artigo será apresentado durante a *11th International Conference on Computing in Civil and Building Engineering* (ICCCBE-XI), a ser realizada em Montreal, Canadá, de 14 a 16 de junho de 2006.

3. *Workspace Challenges for the Oil & Gas Exploration & Production Industry*.

   Co-autores: Alberto B. Raposo, Terrence Fernando e Marcelo Gattass.

   Este artigo foi apresentado durante a *4th Conference of Construction Applications of Virtual Reality* - CONVR 2004, realizada em Lisboa, Portugal, de 14 a 15 de setembro de 2004.

4. *Emergency Environments for the Oil & Gas Exploration and Production Industry*.

   Co-autores: Alberto Raposo, Terrence Fernando e Marcelo Gattass.

   Embora tendo sido um dos artigos selecionados dentre 1200 outros para ser apresentado durante o *18th World Petroleum Congress*, realizado em Johannesburg, África do Sul, de 25 a 29 de setembro de 2005, este Poster não foi apresentado nem publicado porque nenhum dos autores participou do Congresso.

(Disponível em: <http://www.world-petroleum.org/18thwpc/18th%20WPC%20Programme%20Master%2029-03-05.doc> e <www.18wpc.com/about_block1.html>. Acesso em: 4 de março de 2006.)

Finalmente, reproduzimos o resumo da palestra proferida durante o *International Workshop on Virtual Prototyping* realizado de 10 a 11 de março de 2005 em Salford Quays, Manchester, Reino Unido.

- Título: *Virtual Prototyping Challenges for the Oil & Gas Exploration & Production Industry*.

  Co-autor: Terrence Fernando.

  Resumo (Disponível em: <http://www.avprc.ac.uk/abstracts.shtml>. Acesso em: 4 de março de 2006):

  “The oil & gas industry has been a leading player in exploiting the power of virtual reality technology to enhance its business processes. The Virtual Reality Centres (VRCs), large projection rooms with features such as 3D and stereoscopic images, soon became very popular in the oil & gas industry, since they gave specialists the ability to quickly and comprehensively interpret large volume of data, thus significantly reducing cycle time for prospect generation.

  However, due to ever increasing business pressures, there are further demands on researchers to extend the capabilities of the VR technologies, so that they can be fully utilised in all the oil & gas exploration and production (E&P) phases - reservoir exploration, design and construction of the production facilities, and production and transportation of the oil & gas - and their activities, such as 3D geomodelling, seismic interpretation, real-time drilling follow-up and correction, offshore structures' design, static and dynamic simulations of these offshore structures, oil pipelines' monitoring and emergency situations' handling.

This talk presents the main E&P processes of the oil & gas industry that can benefit from the VR technologies and discusses the research challenges emerging from these processes while defining and building virtual prototypes for their activities."

A Multiple-Perspective Architecture for CSCW Applications

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Abstract. We present a mutiple-perspective collaboration metamodel, which mixes Place-Centred and People-Centred perspectives. It allows instances of the metamodel to be derived and experimented until the more adequate to a particular situation is found. It also allows parametric changes in run-time, enhancing the flexibility of the metamodel. The motivation for this work was extracted from the necessity of developing for a global oil & gas company a collaborative virtual workspace for disaster management of oil & gas offshore structures.

Keywords. collaboration modeling, metamodel, collaboration architecture, multiple perspectives, oil & gas

Introduction

Many companies have been creating virtual teams that bring together geographically dispersed workers with complementary skills, increasing the demand for CSCW applications. In order to make the development of a wide range of these collaborative applications more effective, we should offer a general architecture that is adaptable to different situations, tasks, and settings in a flexible way.

CSCW research to date on how to address the architecture characteristic mentioned above has largely focused on issues concerning differences between: *(i)* co-located work and working across distance; or *(ii)* work with people from the same culture or common ground and work with people from different cultures. The previous perspectives have been named, respectively: *Place-Centred* and *People-Centred* [1].

We propose to adopt a different view on the problem based on the activities carried out by the teams participating in the collaborative work. We name it an *Activity-Centred* perspective, which may be seen as a multi-perspective concept since it not only encompasses the Place-Centred and the People-Centred perspectives, but also allows adopting each one or both of them (in a hybrid way) to the desired extent, and admits seamless change from one perspective to another.

The motivation for this work has been the necessity of developing a collaborative virtual workspace for disaster management of oil & gas offshore structures for a global company [2].

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1. Activity-Centred Metamodel

Dewan's generic collaborative architecture [3] structures a groupware application into a variable number of layers from the domain-dependent level to the hardware level, where a layer is a software component corresponding to a specific level of abstraction. Similarly, the Clover architectural metamodel [4] also structures a groupware application into a variable number of layers, decomposing each layer into three functional sub-components dedicated to production, communication and coordination.

Our proposed metamodel adopts a similar multi-level approach, accordingly to Leontjev's [5, 6] activity theory version in which a three-level scheme describes the hierarchical structure of activity. Orthogonally to this approach, similarly to the Clover metamodel, the Activity-Centred metamodel also allows the breakdown of the components correspondent to a specific level. These two orthogonal approaches applied together contribute to the generality of the metamodel.

1.1. Metamodel Abstraction Levels

The top-most level is represented by a complex *node* which encompasses the whole activity. This level can be as diverse as the elaboration of this paper or the disaster management of an oil & gas offshore structure. The level immediately below contains the main actions that should be performed in order to accomplish the activity. These actions are the result of the interactions of groups, with each group represented by a complex node and the interactions among them represented by *edges*.

Splitting downwards each complex node of the upper abstraction level in more elementary nodes, we reach a *leaf node*, which will typically be a *person* or a *software agent*. To those leaf nodes we then associate implementation and hardware attributes such as the application to be executed and the host in which it should be run.

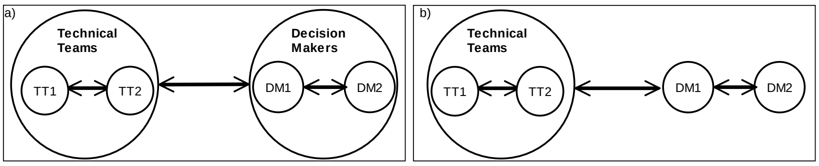

Figure 1. a) The first downward level of the oil & gas company from the disaster management collaborative application. b) Now Decision Maker 1 is placed between the Technical Teams node and Decision Maker 2.

Orthogonally to the top-down process, the Activity-Centred metamodel also allows the breakdown of the components correspondent to a specific level. Let's consider one level of the disaster management example, namely the first one downward of the oil & gas company (Figure 1a). We can observe two main groups: Technical Teams (TT) and Decision Makers (DM). TT is decomposed into sub-groups, and DM, also decomposed into sub-groups. In Figure 1a, both DMs have the same background and level of interaction with TT, while in Figure 1b DM2 has a higher organisational level, with DM1 making the link between TT and him.

1.2. Metamodel Components

1.2.1. Nodes and Edges

Nodes are essential components of our metamodel, going from the top-most node representing the whole activity through many nodes of different levels representing groups and sub-groups until the *leaf nodes* representing a *person* or a *software agent*. Nodes have a set of *attributes* such as user interface preferences and language used, which are applied using a hierarchical class concept.

Nodes also have an attribute called *artifacts* defined as “all objects on which users can operate” [7]. Examples of artifacts are drawings, physical models, prototypes, and documents. Following the class concept, an artifact associated with a group node is shared by all members in the group, unless otherwise explicitly stated. In this case, a mechanism such as an access control list will determine who share access to the artifact.

Edges in our metamodel represent the *interaction paths* among nodes, which can be uni or bi-directed. When an edge is represented by a thin arrow, this means that the nodes on its extremities are co-located. When the arrow is thick, the nodes are placed remotely to each other. Edges have one important element, *channel*, which represents the electronically mediated channel that allows communication between two nodes.

1.2.2. Edge Especialisation Elements

We have identified the need for additional *edge especialisation elements*, namely *pre-* and *post-communication processings*, which are separated into two different classes. The first class is constituted by the ones directly associated with the leaf nodes. They represent the processings to be executed particularly onto a specific message being passed between two nodes and are stored in an especial table with key (message_id, receiver). The second class is constituted by the ones associated with groups on different levels of the metamodel hierarchy, representing the policies of these groups when respectively sending (*out-policies*) and receiving (*in-policies*) messages.

In Figure 2, we show possible pre- and post-communication processings that could be executed while sending a message from a Computer Science Researcher CR1 of the Computer Science Dept. CD1 of University U1 to Researcher CR2 of University U2.

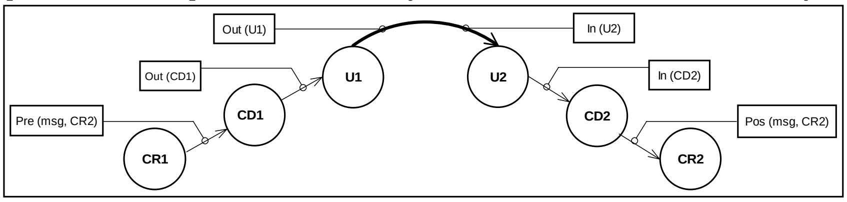

Figure 2. Activity-Centred metamodel: pre- and post-communication processings.

At the sender side, the natural candidate to execute the pre-processings is the leaf node who is sending the message. At the receiver side, this could be accomplished adding an attribute to the first group node pointed by the edge (in our example, U2) corresponding to the leaf node of this group to execute the post-processings.

Regarding the algorithms to be executed when sending a message, it is important to note that each message has one initial sender, which is necessarily a leaf node, and one or more final receivers, which can be either leaf or group nodes. The algorithms to be executed at either side are shown in Table 1.

1.2.3. Role Rules and Message Attributes Table

Role rules for coordination structure have been employed in CSCW for more than one decade [8, 9]. According to the majority of these studies, we adopted the strategy of separating the coordination structure and the computational program, using a logic-based specification language for specifying coordination policies.

Table 1. Activity-Centred metamodel: sender and receiver algorithms.

sender (sender, receiver, flag)
- until the receiver is found repeat
  - at the current level, search for the sub-tree that contains the receiver
  - if the receiver is found (and all the path from the sender to the receiver is determined)
    - if flag = in_table
      - execute the pre-processing associated with the pair (message, receiver)
    - else
      - create a new line in the message attributes table with pair (message, receiver) indicating the post-processing to be executed
    - execute all the out-policies associated with groups on levels in the path beginning at the sender until the communication edge is reached
    - send the message with the receiver to the leaf node which is assigned to the post-processing attribute of the receiver group node, or to the receiver itself
  - else
    - go to the upper level

Sender side of the communication edge (executed by the initial_sender leaf node):
- for each final_receiver associated with the message
  - sender (initial_sender, final_receiver, in_table)

Receiver side of the communication edge:
- receive the message
- execute all the in-policies associated with groups on levels in the path beginning at the present node until the final_receiver node is reached
- if the final_receiver is a leaf node
  - if it is equal to the post-processings execution node:
    - execute the post-processing associated with the pair (message, final_receiver)
  - else
    - send the message to the final_receiver
- else
  - execute the post-processing associated with the pair (message, final_receiver), which in this case should determine the leaf node(s) or group node(s) to receive the message
  - for each of the node(s) determined above (current_node)
    - sender (final_receiver, current_node, not_in_table)

We declare a *collaboration bus*, used to connect all participants, having at least one *channel* declaration. Different collaborations may be executed at the same time, each with its correspondent collaboration bus. The set of participants who are governed by the same set of coordination policies is playing the same *role*. When these policies also define the order in which the events occur, they can be considered workflow rules. Communication among participants occurs through one or more message channels associated with one collaboration bus. Similarly to COCA [9], the basic tasks of receiving messages and sending out messages are: *(i)* for receiving messages, an active rule named *on-arrive* with arguments *channel*, *receiver*, *message_id* (and *sender*); *(ii)* for sending out messages, a *send* formula with arguments *channel*, *sender*, *message_id* (and *receiver*).

We also build a *message attributes table* to enhance the flexibility of the coordination program, separating coordination rules from data related specifically to each message. This table provides an indirection that enables dynamic reconfiguration.

2. Instanciating the Activity-Centred Metamodel: Activity-Centred Models

Sometimes the most important aspects of our collaborative application are related to the place where people are effectively working. A model using this *Place-Centred* perspective for a paper elaboration collaborative application is shown in Figure 3a. There, we have three main nodes: PUC University, Salford University and Petrobras (BR, Brazilian oil & gas company). The central node, playing the main role in writing the paper, is PUC, which communicates remotely with both Salford University and Petrobras. Within PUC, we have two sub-groups: one is the Computer Science (CP, C for Computer and P for PUC) Department, which has two co-located researchers, and the other is the Engineering department, which has one single Engineer (EP1). The two departments, being in different buildings, also communicate remotely. In Salford, there is only one Computer Science researcher, and in Petrobras, two co-located Engineers.

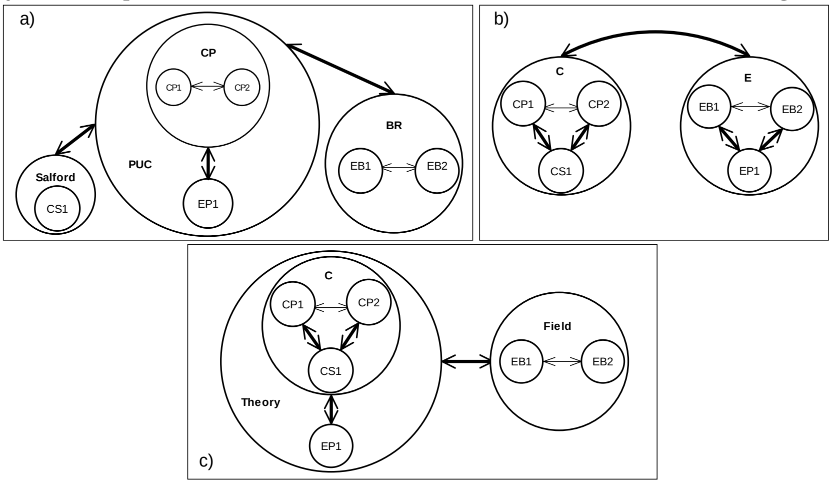

Figure 3. The paper elaboration collaborative application: a) a Place-Centred perspective; b) a People-Centred perspective; c) an Activity-Centred perspective.

Now consider that the main concerning issues of our collaborative application are related to culture and common ground barriers. In this case, we should derive a model with a *People-Centred* perspective (Figure 3b). We now have only two main nodes: the Computer Science researchers' (C) group and the Engineers' (E) group, communicating remotely. Within C group, we have three researchers: CP1 and CP2 work co-located and CS1 works remotely. It is important to note that, although CS1 is from a different university than CP1 and CP2, their common ground is so intense that they belong to the same sub-group. The same reasoning is applied to the E group.

We now mix the two previous perspectives in what we call an *Activity-Centred* perspective. In the present collaborative application, it seems more adequate to focus on the whole activity being performed – the paper elaboration – and then derive the groups to be formed. To elaborate the paper, authors CP1, CP2, CS1 and EP1 try to derive a new theoretical model based on the requirements' identified through field study, working together with Engineers EB1 and EB2. So we aggregate those people in two main groups formed based on their main activity: the Theory group and the Field group, which communicate remotely (Figure 3c).

3. Case Study

We now focus on the case study that motivated the creation of our metamodel: the development of a collaborative virtual workspace for disaster management of oil & gas offshore structures for the Petrobras Research and Development Centre.

The disaster management of an oil & gas offshore structure is a complex operation involving three main groups: the oil & gas company, the Rescue Team and the Health Care Centre. This is an inter-organisational complex activity led by the oil & gas company, whose node will be detailed. An overall picture of the disaster management collaborative application is depicted in Figure 4.

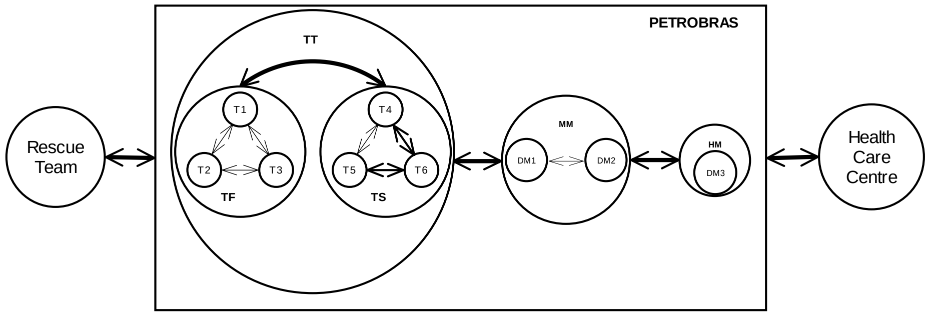

Figure 4. The disaster management collaborative application: overall picture.

Within Petrobras node, we identify three main groups: the Technical Teams (TT), the Middle-level Managers (MM) and the High-level Managers (HM), each one remotely located to the other. TT is formed by two technical sub-groups: the Task Force (TF) team and the Technical Support (TS) team, also remotely located.

TF plays the main role, leading the make-decision process. It is constituted by three co-located technicians, such as naval engineers, structural engineers, risers analysts or oceanographers. TF runs different simulators to derive the best solution to save the offshore unit, permanently communicating with TS. They also maintain contact with MM informing about their work evolution and asking for approval for their derived solution. Once their solution is approved, they pass the sequence of commands to be executed to the unit operator (not represented in our picture).

TS team, with technicians working in the same fields as TF team, can be invoked by TF team to perform especialised simulations focusing on some particular issues that would not be possible to be done by TF, or to obtain another opinion about the problem.

MM is constituted by middle-level managers working co-located in a company office, with one of them usually being the responsible to make the final decision. They have an overall knowledge about the technical issues and work constantly interacting with the TT group. They also communicate with the HM group, informing about the work evolution and eventually when they need to make a more critical decision.

3.1. Prototype

After investigating the activities involved in this disaster scenario, identifying their requirements in terms of ICT, we decided to concentrate on the Technical Teams group to develop a prototype of collaborative application implementing a particular model of our Activity-Centred metamodel. This prototype is particularly related to the work performed by the Task Force group (TF), including the simulators they run, their mutual communication and their interaction with the Middle-level Manager group.

We first investigate how TF runs the different simulators and what are the relationships among them. During a crisis situation, Petrobras typically uses three simulators. The first simulator to be run is SSTAB [10], the Floating Units Stability system. The second simulator is called WAMIT and uses as input the results from SSTAB. The third simulator is DYNASIM [11], for Dynamic Stability. It uses as input the results obtained from WAMIT as well as additional parameters related to environmental conditions. DYNASIM calculates the forces acting on the mooring lines and risers. When these forces are considered extreme, a retrofeedback process is started, performing all the simulations again, beginning with SSTAB, to find another stable condition of the unit.

An Activity-Centred model representing this crisis situation (Figure 5a) can be derived based on the participants' roles. We created two remote groups: Technical Teams (TT) and Decision Makers (DM). TT is constituted by the Task Force (TF) team with members T0, T1 and T3, and the agent S2. DM is constituted by a single manager, a representative of all participants not directly involved with the technical part of the simulation activity such as operators and other managers, who only receive from TT follow-up messages, commands to be executed or approval requests.

Other than the interaction network part of the model just described, we also define rules and the message attributes table in order to represent the following workflow.

The Crisis Pilot T0 plays the main role in this disaster application, coordinating the collaborative session and leading the make-decision process. He asks for the SSTAB operator (T1) to begin his simulation. After receiving a message from agent S2 indicating the end of its simulation, he asks for DYNASIM operator (T3) to begin his simulation. On receiving a simulation conclusion message from T3, he makes a decision based on the force values acting on mooring lines and risers. If he understands that these forces are extreme, he asks for T1 to begin all the process again, in order to find a new stable condition of the unit, and this loop continues until he is satisfied with the force values obtained. In this case, he makes contact with DM1, asking for his approval to their solution.

The basic conceptual level architecture of our collaborative application is shown in Figure 5b.

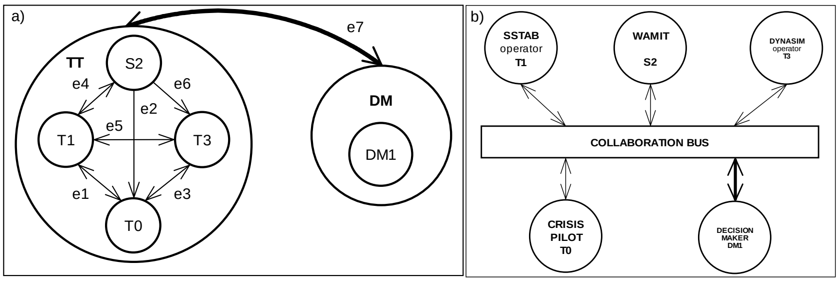

Figure 5. A first model of the disaster management collaborative application (a) and its prototype (b).

In order to map our model into an implementation-level architecture, we investigated different approaches, having in mind two main requirements: real-time support and open-source standard to develop prototypes. We chose HLA – High Level Architecture [12, 13], which not only fulfils our requirements but also is a flexible component-based architecture, in accordance to the principles we have been pursuing.

4. Conclusions and Future Work

We propose a multiple-perspective metamodel, which mixes Place-Centred and People-

Centred perspectives. It employs not a technology-driven but a human- and socially-centred approach. Associating pre- and post-communication processings to each of these levels, we could accommodate policy and privacy rules of organisations, even allowing inter-organisational work.

The metamodel allows flexibility in many dimensions. Separating high-level abstraction features from low-level implementation features allows the designer and the application developer to concentrate on their particular domain of expertise. Separating the computational program and the coordination program allows programmers to concentrate on coordination issues with high-level abstraction.

The metamodel is also customisable in the sense that it allows associating pre- and post-communication processings with each message sent. It allows parametric run-time changes such as changing names of pre- and post-communication processings in the message attributes table, or even changing the pre- and post-communication codes before they have been loaded during a collaborative session.

There is still a lot of work to do in order to make our metamodel a fully flexible and evolving collaborative architecture. For example, we should investigate how to promote our metamodel from a customisable category to an adaptable category [14], upgrading from the capability of adjusting parametric controls to the capability of reconfiguring its behaviour according to immediate patterns of use. We could accomplish this using a learning mechanism to monitor the users' activities.

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CONFIGURING A COLLABORATIVE VIRTUAL WORKSPACE FOR DISASTER MANAGEMENT OF OIL & GAS OFFSHORE STRUCTURES

Enio Emanuel Ramos Russo [1], Alberto Raposo [2], Terrence Fernando [3], Marcelo Gattass [4], and Börje Karlsson [5]

ABSTRACT

There are serious risks involved in running offshore units, with many reported disasters. These disasters can not only cause deaths and important environmental impacts, but also have a strong impact on business. Oil & gas companies are thus continuously seeking to employ processes and technologies to respond to such events in order to ensure safety. Such processes involve collaboration among a large number of groups and resources from different natures and geographically distributed, in order to make appropriate decisions within a short period of time. These groups are comprised of many technical experts and decision makers such as naval engineers, structural engineers, risers analysts and oceanographers, as well as managers. They need to be in constant communication with operators inside the unit, divers, security team, and, perhaps, with experts who are travelling to execute the rescue plan.

This work investigates how a distributed workspace environment can support disaster management, involving distributed collaborative technical teams. We first identify the requirements for the distributed workspace, from the stakeholders involved in a disaster, and analyse the commercial emergency systems available. We then elaborate a multi-perspective metamodel to support configuring this collaborative virtual workspace. Finally a prototype for oil & gas offshore structures disaster management based on our multi-perspective metamodel is derived and an HLA-compliant implementation for this prototype is developed as a proof-of-concept of the metamodel.

KEY WORDS

collaborative virtual workspaces, distributed environments, HLA, decision making, oil & gas

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INTRODUCTION

There are serious risks involved in running offshore units, with many reported disasters. Companies can lose billion of dollars by losing an offshore unit and further billions of dollars due to the cease of the oil production. As a direct result of these huge accidents, the oil & gas companies usually take actions in two main directions: *(i)* one that has the objective of correcting and improving the operational procedures; and *(ii)* a second one that has the aim of planning a set of projects to improve the technological level of the company in order to minimize the risk of future accidents (Costa 2004).

Considering the second aspect and the necessity of minimizing disaster impacts, we verify the need to develop a system architecture capable of bringing people together to work as a virtual team to explore various rescue plans and work towards consensus.

Many companies have been creating virtual teams that bring together geographically dispersed workers with complementary skills, increasing the demand for CSCW (Computer Supported Cooperative Work) applications. In order to make the development of a wide range of these collaborative applications more effective, we should offer a general architecture that is adaptable to different situations, tasks, and settings in a flexible way. The motivation for this work has been the necessity of developing a collaborative virtual workspace for disaster management of oil & gas offshore structures for a global company (Russo et al. 2004).

The main aim of this work is to investigate how a distributed workspace environment can support disaster management, involving distributed collaborative technical teams. Specifically, this research will focus on a distributed workspace for technical groups to work as a collaborative virtual team to explore various simulation options and to communicate their results to the decision makers. This aim will be achieved through the following objectives: *(i)* to conduct a survey to identify the requirements for the distributed workspace, from the stakeholders involved in a disaster scenario; *(ii)* to elaborate a metamodel to configure collaborative virtual workspaces; and *(iii)* to define a distributed workspace environment based on this metamodel for the technical team to engage in the rescue efforts.

REQUIREMENTS GATHERING

Petrobras, Brazilian Oil & Gas Company, faced two major accidents in the beginning of this decade. In 2001, the largest semi-submersible platform in the world P-36 sunk, killing 11 employees and ceasing a daily production of 84,000 barrels of oil and 1.3 million cubic meters of natural gas. In 2002, the FPSO (Floating Production, Storage and Offloading) unit P-34 with a daily production of 35,000 barrels and a storage capacity of 58,000 m^3 of oil had a stability problem and almost sunk, immediately ceasing its operation. At this time, Petrobras managed to rescue the unit without loss of lives.

The requirements gathering for the distributed workspace has been obtained through Petrobras case studies P-36 and P-34. These case studies have been used to identify the roles and attributes of people involved in a typical disaster management operation. Structured interviews have also been carried out to identify procedures and the users' expectations about the collaborative workspace. In this type of environment, it is important to model the users' relationships and to identify the main collaborative features that the users would like to have.

Once the users' requirement capture phase was completed, the next step was to define the technical requirements in terms of collaboration models, simulation steering, personalised and global workspaces, synchronised viewing, video-streaming, etc. We then conducted a survey on the main commercial emergency management systems available to gather their main characteristics and the main features still underdeveloped.

EVOLUTION OF DISASTER MANAGEMENT IN PETROBRAS

This section illustrates the complexity of the problem in terms of processes and groups of people involved in such disaster incidents. From this discussion, we show that Petrobras has been continuously active in improving its disaster management program.

During the P-36 disaster, there was a mechanical explosion and a chemical explosion with loss of lives, which caused difficulty in acting quickly to save the unit. During the P-34 disaster, there was no explosion, enabling the teams to react quickly, although the communication among them could still be improved. This research aims to make the next step change in terms of using ICT (Information and Communication Technology) to improve the collaboration between the stakeholders involved in disaster incidents.

In the case of the P-36 disaster, Petrobras identified the need for updated emergency procedures and for executing the actions within a short period of time in order to save the unit. This case aroused the need to investigate collaborative and decision-making models to help complex teams in avoiding disasters. In the case of P-34, there was already an updated model of the offshore unit and a form of distributed working that did help the rescue team to act quickly. There was also a static simulator that allowed the specialists to run different simulations. Nevertheless, the team still did not have an adequate environment to work as a virtual team to share knowledge, jointly discuss possible rescue plans, and to work quickly towards consensus.

As a result, it was necessary to bring people together into the same physical location with some delay in the process. Furthermore, some of the information was not directly available to the decision makers. This incident showed the necessity to strengthen the collaboration among the distributed teams providing better interaction, simulation and discussion during the whole rescue operation.

DISTRIBUTED NATURE OF THE TEAMS AND THE RESOURCES

In the case of Petrobras, when an accident occurs, the head office is immediately contacted and the General Manager of the operational unit is in charge of crisis management. All the work will be under his control in the decision workspace. The Security, Environmental and Health Dept. then starts emergency procedures and at the same time the technical specialists begin to act. In the technical workspace, there are naval engineers, structural engineers, risers analysts and oceanographers. When working together in a collaborative way there are usually the following main distributed groups: *(i)* the high-level decision team at the operational unit; *(ii)* a task force group leading the make-decision process; *(iii)* a technical support team at the company headquarters, at the Business Unit, and at the research center; and *(iv)* mobile experts, who sometimes are overseas or travelling and who must also be connected.

In addition to these groups, and working together with them, there are security teams in rescue units which are moved towards the region of the accident and give help during all the crisis period.

Not only the experts, but also the system resources are distributed in this scenario. For example, the computer intensive simulators may have to remotely run on a super computer or on a cluster of computers to get quick results. Also, the environment may need access to remote databases which maintain CAD models and simulation models of the unit.

In terms of configurations, each site participating in the crisis solution can have different ones, such as a Virtual Reality Centre, an intranet desktop and a laptop connected to the network. Moreover, experts who are travelling may have to be linked via mobile technologies and the connection between the unit and the people on earth may vary.

COMMERCIAL EMERGENCY MANAGEMENT SYSTEMS

After having determined the collaborative disaster management workspace requirements, we conducted a survey on the main commercial emergency management systems available. We identified the main characteristics of those systems, the main areas already covered, what is the state-of-the-art and what are the main features which are still underdeveloped.

While performing this survey, existent Emergency Management Systems from some vendors were investigated: L-3 CRISIS Command and Control System (MPRI Ship Analytics 2003); Oil Spill Crisis Management Simulator, also from Ship Analytics; and U.S. Automated Resource Management System (ARMS) Systems Requirements Document (Booz Allen Hamilton 2003). Crisis Intervention methods – the Crisis Intervention and Operability (CRIOP) Analysis (Johnsen et al. 2004) – being practiced in companies such as Statoil, Norsk Hydro, Elf and BP, were also investigated.

From this survey, we concluded that most of the Emergency Management Systems have some common characteristics, such as: serving as an incident management as well as a training and planning tool; having capability of integration, not only with internal databases and systems, but also with public emergency management systems; normally providing a Geographical Information System (GIS), which is responsible for displaying real-time data of the incident; and providing logging and tracking capabilities of resources and activities, as well as checklists as an efficient method to address the multiple simultaneous requirements.

In spite of all the features listed above, we identified two main drawbacks of current Emergency Management Systems: *(i)* lack of suitable integration of simulators with high performance visualisation systems; and *(ii)* inadequate security and access control features.

The survey demonstrated that, in spite of the integration of most of the Emergency Management Systems with simulators, there is the need to develop a system architecture capable of supporting distributed resources, mainly distributed simulators running on *high performance* visualisation systems. This architecture should also provide synchronous communication among different equipments with virtual co-location as one feature.

The integration of simulators using high performance visualisation systems in a synchronous distributed environment is the aspect of the emergency scenario on which we are going to focus. In order to support the definition of the architecture of this environment, a metamodel will be elaborated.

A METAMODEL TO CONFIGURE COLLABORATIVE VIRTUAL WORKSPACES

CSCW applications have largely focused on issues concerning differences between: *(i)* co-located work and working across distance; or *(ii)* work with people from the same culture, or common ground, and work with people from different cultures. The previous perspectives have been named, respectively: Place-Centered and People-Centered (Jones et al. 2004). We propose to adopt a different view on the problem based on the activities carried out by the teams participating in the collaborative work. We name it an *Activity-Centered* perspective, which may be seen as a multi-perspective concept since it not only encompasses the Place-Centered and the People-Centered perspectives, but also allows adopting each one or both of them in a hybrid way, and admits seamless change from one perspective to another.

Nodes are essential components of our metamodel, going from the top-most node representing the whole activity through many nodes of different levels representing groups and sub-groups until the leaf nodes representing a person or a software agent. Nodes also have an attribute called *artefacts* defined as “all objects on which users can operate” (Gross and Prinz 2004). Examples of artefacts are drawings, physical models, prototypes, and documents. Following the class concept, an artefact associated with a group node is shared by all members in the group, unless otherwise explicitly stated. In this case, a mechanism such as an access control list will determine who share access to the artefact.

Edges in our metamodel represent the interaction paths among nodes, which can be uni- or bi-directed. When an edge is represented by a thin arrow, this means that the nodes on its extremities are co-located. When the arrow is thick, the nodes are placed remotely to each other. Edges have one important element, *channel*, which represents the electronically mediated channel that allows communication between two nodes.

We take an overall picture of the disaster management collaborative application (Figure 1) to illustrate the metamodel components. The disaster management of an oil & gas offshore structure is a complex operation involving several groups, such as the oil & gas company, the rescue team, the health care centre, the press, among others. This is an inter-organizational complex activity led by the oil & gas company, whose node will be detailed.

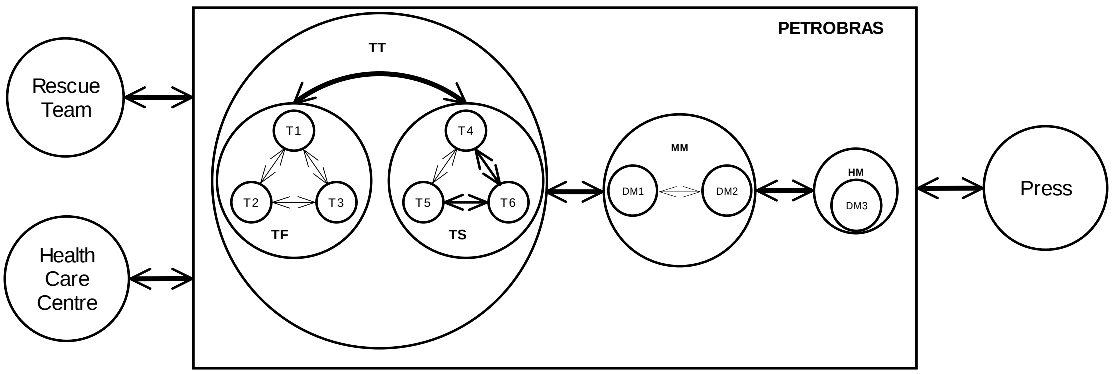

Figure 1: The disaster management collaborative application: overall picture

Within Petrobras node, we identify three main groups: the Technical Teams (TT), the Middle-level Managers (MM) and the High-level Managers (HM), each one remotely located to the other. TT is formed by two technical sub-groups: the Task Force (TF) team and the

Technical Support (TS) team, also remotely located.

TF plays the main role, leading the decision making process. It is constituted by three co-located technicians, such as naval engineers, structural engineers, risers analysts or oceanographers. TF runs different simulators to derive the best solution to save the offshore unit, permanently communicating with TS. They also maintain contact with MM informing about their work evolution and asking for approval for their derived solution. Once their solution is approved, they pass the sequence of commands to be executed to the unit operator (not represented in our picture).

TS team, with technicians working in the same fields as TF team, can be invoked by the latter to perform specialized simulations focusing on some particular issues that would not be possible to be done by TF, or to obtain another opinion about the problem.

MM is constituted by middle-level managers working co-located in a company office, with one of them usually being the responsible to make the final decision. They have an overall knowledge about the technical issues and work constantly interacting with the TT group. They also communicate with the HM group, informing about the work evolution and eventually when they need to make a more critical decision.

In our metamodel, we have also identified the need for additional *edge specialization elements*, namely *pre*- and *post-communication processing*, which are separated into two different classes. The first class is constituted by the ones directly associated with the leaf nodes. They represent the processing to be executed particularly onto a specific message being passed between two nodes. The second class is constituted by the ones associated with groups on different levels of the metamodel hierarchy, representing the policies of these groups when respectively sending (*out-policies*) and receiving (*in-policies*) messages. In Figure 2, we show possible pre- and post-communication processings that could be executed while sending a message from a Computer Science Researcher CR1 of the Computer Science Dept. CD1 of University U1 to Researcher CR2 of University U2.

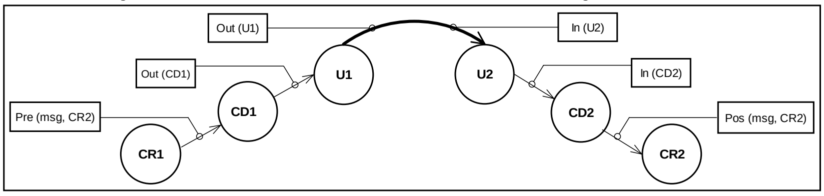

Figure 2: Activity-Centered metamodel: pre- and post-communication processings

According to the majority of CSCW studies (e.g., Cortés and Mishra 1996, Li and Muntz 1998), we adopted the strategy of separating the coordination structure and the computational program, using *role rules* with a logic-based specification language for specifying coordination policies. We also built a *message attributes table* to enhance the flexibility of the coordination program, separating coordination rules from data related specifically to each message. This table provides an indirection that enables dynamic reconfiguration.

PROTOTYPE

After investigating the activities involved in the disaster scenario and identifying their requirements in terms of ICT, we decided to concentrate on the Technical Teams group to develop a prototype of collaborative application implementing a particular model of our Activity-Centered metamodel. This prototype is particularly related to the work performed by the Task Force group (TF), including the simulators they run, their mutual communication and their interaction with the Middle-level Manager group.

During a crisis situation, the Task Force group typically uses three simulators. The first simulator to be run is SSTAB (Coelho et al. 2003), the Floating Units Stability system, used to analyse the static conditions of the floating unit (Figure 3a). SSTAB uses as its inputs the unit model obtained from a centralized system and updated data from the unit obtained through a monitoring system. It gives as outputs five files, including the inertia matrix.

The second simulator is called WAMIT and uses as inputs the output files generated by SSTAB. It works in the frequency domain, deriving the excitation forces of the unit and water forces reactions to lateral displacement. WAMIT is activated by a user interface program called WMG.

Finally the third simulator to be executed is DYNASIM (Coelho et al. 2001), for Dynamic Stability (Figure 3b). It uses as inputs the results obtained from WAMIT as well as the parameters representing the *height* and the *period* of the waves at the moment of the disaster. DYNASIM calculates the forces acting on the mooring lines and risers. When these forces are considered extreme, a retrofeedback process is started, performing all the simulations again, beginning with SSTAB, to find another stable condition of the unit.

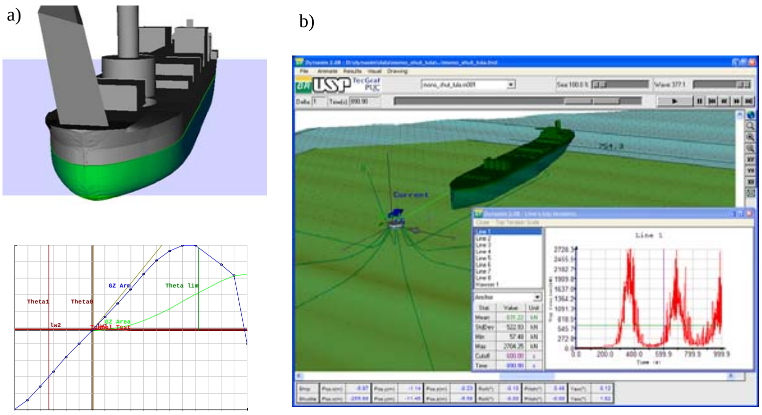

Figure 3: a) SSTAB; b) DYNASIM

The method used to save an offshore unit has the goal of defining a sequence of commands to be passed to the unit operators or to the rescue team so that they can move the unit in a step by step mode from its initial unstable condition until it reaches back its normal equilibrium state. It is based on the following workflow:

- We first use these three simulators to derive the initial conditions of the offshore unit.
- We then define a next step configuration of tanks (e.g., moving water from a ballast tank of one side to a ballast tank of the opposite side) and simulate the unit in this new condition using again the simulators. If we are not satisfied with the results, we define another configuration of tanks and continue this process, experiencing

iteractively configurations, until we are satisfied.

- From the configuration of the previous step, we now try to derive a new step configuration of tanks, using a process analogous to the one just described.
- We repeat this process of deriving step configurations of tanks using our three simulators until we reach back a normal equilibrium state.

At the end of this whole process, we have a sequence of commands in terms of tanks' valves operations, correspondent to the achievement of each of the step configurations described above, in a step by step mode, which was exactly our goal.

It is important to note that the executions of simulators SSTAB and DYNASIM are highly interactive visualisation processes, mainly in a crisis situation, when we need to rapidly experiment many alternatives to respond to the disaster. Also we have to consider that, in emergency situations, it is very important to be as fast as possible. Then, searching for points where we could save time, we found that, if WAMIT receives the results from SSTAB, it can be activated automatically on ending the SSTAB simulation.

An Activity-Centered model representing this crisis situation (Figure 4a) can be derived based on the participants' roles. We created two remote groups: Technical Teams (TT) and Decision Makers (DM). TT is constituted by the Task Force (TF) team with members T0, T1 and T3, and the software agent S2. DM is constituted by a single manager, a representative of all participants not directly involved with the technical part of the simulation activity such as operators and other managers, who only receive follow-up messages, commands to be executed or approval requests.

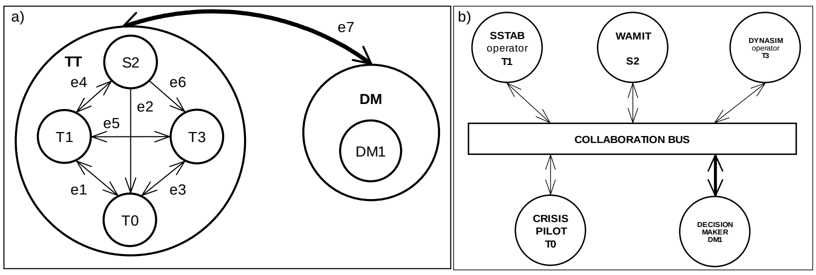

Figure 4: A first model of the disaster management application (a) and its prototype (b)

Other than the interaction network part of the model just described, we also define role rules and the message attributes table in order to represent the following workflow.

The Crisis Pilot T0 plays the main role in this disaster application, coordinating the collaborative session and leading the make-decision process. He asks for the SSTAB operator (T1) to begin his simulation. After receiving a message from agent S2 indicating the end of its simulation, he asks for the DYNASIM operator (T3) to begin his simulation. On receiving a simulation conclusion message from T3, he makes a decision based on the force values acting on mooring lines and risers. If he understands that these forces are extreme, he asks for T1 to begin the whole process again, in order to find a new stable condition of the unit, and this loop continues until he is satisfied with the force values obtained. In this case, he makes contact with DM1, asking for his approval to their solution. The basic conceptual level architecture of our collaborative application is shown in Figure 4b.

In order to map our model into an implementation-level architecture, we chose HLA – High Level Architecture (IEEE 2000), with real-time support and a flexible component-based architecture. The fundamental concepts in HLA are: *(i)* Federate – a simulation implemented as part of an HLA-compliant simulation; and *(ii)* Federation – a collection of federates working together. We use XRTI – The Extensible Run-Time Infrastructure (Kapolka 2003) as the HLA run-time infrastructure, an open-source and freely distributable implementation, written in Java and using XML object models. Among its basic characteristics we have: *(i)* a dynamic object model extension and composition support; *(ii)* a pure client-server topology in which federates only communicate with one another through the XRTI Executive, a server application; and *(iii)* Federates maintain two channels to the Executive: a TCP channel for reliable communication and a UDP channel for unreliable messaging.Observing the model of Figure 4a, we conclude that all participant members can constitute a single Federation. We then associate a Federate with each participant of this Federation. Each Federate code is a Java program built based on the workflow rules written in a logic-based program. To enhance flexibility, the main method of each Federate is the one named *process_role*, which receives as parameter the role to be played by the Federate, coded in a separate Java module. Using this strategy, we can code the workflow rules associated with a specific role directly into a separate module dedicated to this role.

CONCLUSIONS

This work was motivated by and was conducted in real-world settings, namely an oil & gas offshore structure disaster scenario. This seems to contribute to the CSCW field, since a review of CSCW evaluation studies concluded that less than half were conducted in real-world settings (Pinelle 2000). An adequate model to the disaster scenario was derived from our multi-perspective metamodel. We also implemented a first prototype as a proof-of-concept of our metamodel, using an HLA run-time infrastructure.

The metamodel allows flexibility in many dimensions. Separating high-level abstraction features from low-level implementation features allows the designer and the application developer to concentrate on their particular domain of expertise. Separating the computational program and the coordination program allows programmers to concentrate on coordination issues with high-level abstraction.

The metamodel is also customisable in the sense that it allows associating pre- and post-communication processings with each message sent. It allows parametric run-time changes such as changing names of pre- and post-communication processings in the message attributes table, or even changing the pre- and post-communication codes before they have been loaded during a collaborative session.

There is still a lot of work to do in order to make our metamodel a fully flexible and evolving collaborative architecture. Particularly to the situation of an emergency scenario being considered, it would be very important to include an Expertise Recommender system, such as the one proposed by McDonald and Ackerman (2000), since in a crisis situation it is fundamental to locate the expertise necessary to solve the problem in the lesser possible time. We should also investigate how to promote our metamodel from a customisable category to an adaptable category (Dourish 1998), upgrading from the capability of adjusting parametric controls to the capability of reconfiguring its behaviour according to immediate patterns of use. We could accomplish this using a learning mechanism to monitor the users' activities.

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Workspace Challenges for the Oil & Gas Exploration & Production Industry

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Abstract
The objective of this paper is to present some of the key challenges faced when defining and building virtual workspaces for oil & gas Exploration & Production (E&P) activities. First, we present the main E&P processes that can benefit from the VR technology. Secondly, we classify and describe the different challenges.

Keywords
virtual environments, virtual workspaces, oil & gas, E&P processes.

1. INTRODUCTION

The oil & gas industry has been a leading player in exploiting the power of virtual reality technology to enhance its business processes. The motivation for deploying such advanced technology in this industry is due to the difficulties that the companies were facing in the late nineties, with the price of oil hovering near all-time lows. At that time, the pressure to reduce exploration and development costs of new reserves and existing fields was immense and the immersive virtual reality technology was identified, by the oil & gas industry, as one of the key tools which can meet these challenges. The Virtual Reality Centres (VRCs), large projection rooms with features such as 3D and stereoscopic images, soon became very popular in the oil & gas industry, since they gave specialists the ability to quickly and comprehensively interpret large volumes of data, thus significantly reducing cycle time for prospect generation [American98].

However, due to ever increasing business pressures, there are further demands on researchers to extend the capabilities of the VR technologies, so that it can be fully utilised in all the oil & gas exploration and production (E&P) phases. This paper presents various E&P processes of the oil and gas industry and discusses research challenges emerging from these processes.

The structure of this paper is as follows. Initially, Section 2 presents the key E&P processes and their application demands. Section 3 presents the classes of technology challenges emerging from these E&P processes for VR. The final conclusion of this paper is presented in Section 4.

2. TYPES OF E&P PROCESSES

This section discusses the main processes of the oil & gas E&P industry and the main challenges within each process. The work presented here is based on the authors' experience with oil & gas projects at Petrobras in Brazil.

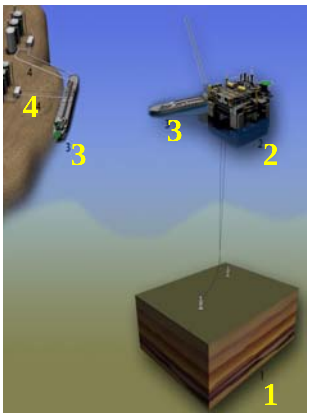

Figure 1: (1) reservoir; (2) offshore platform; (3) transportation ships; (4) oil pipelines.

Figure 1 shows the main resources involved in the production of oil & gas. The typical E&P processes in the oil & gas industry are: (i) reservoir exploration through 3D geomodelling and seismic interpretation; (ii) design and construction of the production facilities based on the results of the first phase; and (iii) production and transportation of the produced oil & gas.

The following subsections describe how virtual reality can enhance each of these E&P phases.

2.1 Reservoir Exploration Phase

During this exploration phase, the goal is to elaborate the subsurface models that best represent the reservoirs.

Whether it is a seismic cube or a stratigraphic geological model, what is important in this phase is to build an individual mental representation of the model. Therefore the key tasks in this phase are 3D geomodelling and 3D seismic interpretation.

Drilling wells for crude may consume up to 85% of the total exploratory funds. Thus, the decision to drill should be taken in a sensible way based on studies that provide detailed knowledge of the area's geologic conditions, both on the surface and in the subsurface. Of all such studies, the seismic method is more decisive to select the drilling spots. Seismography makes use of subsurface ultrasonography, generating seismic logs that provide an approximate image of the configuration of several subsurface strata.

3D geomodelling involves a large spectrum of skills, spread over different domains (geophysics, geology, reservoir and petroleum engineering). During its lifetime, a numerical earth model is shared by people with different types of specializations. The model evolves continuously over time, by absorbing various inputs from the team members [Reis01].

Seismic interpretation in the late seventies used to be made over a stack of paper maps, from which the interpreter would pinpoint areas of interest for drilling by creating a mental 3D image about thickness, constitution, depth and performance of rock beds. However, the advent of VRCs and stereoscopic images opened a door to a new world for seismic interpretation, allowing the users to visualise and explore in an interactive manner. The work became much more easier since specialists no longer need to use their knowledge and imagination to draw a mental picture of the area and to feel immersed in it. A mapping that used to take months began to be drawn in just a few hours [Petrobras99].

The viability to use 3D imaging fosters a more accurate and faster interpretation of the external geometry and internal architecture of reservoirs. With all the participants of a project having access to the same shared viewing, one can have a better interpretation of a large pile of data, achieving more reliable simulations of the oil output performance of that reservoir and analysis of its results. The team can calculate curves for future production, forecast the number of wells for drilling and devise the whole project for an oilfield development [Petrobras99].

The images can be studied until specialists are able to determine the best way to exploit the reservoir they represent. Well location, rock qualities and the distribution of well fluids (water, gas and oil) can be analysed more efficiently with the purpose of ascertaining the best distribution patterns for production and injection wells [Petrobras01].

One of the current key challenges in this area is the development of collaborative workspaces for supporting truly collaborative geomodelling and visualization for distributed users. Given the geographical dispersion of experts in the oil & gas E&P industry, remote collaboration offers great benefits, particularly in activities involving continuous model refinement and decision taking.

Another challenge is to develop better interaction facilities with real-time performance to explore the seismic data in a more interactive manner. This requires both heavy processing power and intuitive interfaces designed for team work. Two approaches could be explored in providing the computer power necessary for real-time seismic data exploration: PC cluster approach and computational steering from super-computers. Although both approaches are sensible from the research point of view, the PC cluster approach seems to be favoured by many due to the cost factor. The interfaces for controlling the simulation and visualisations, generated by these computers, need to be enhanced to provide natural interaction. The deployment of emerging technologies such as wireless tracking, PDAs, gesture-based interaction to develop natural interfaces for the team collaboration is still a challenging research problem.

Real-time follow-up and correction of the course of a deepwater horizontal well is one of the activities that can also take advantage of the VRCs' features. Although this technology may be used in any kind of well, its potential is clearly shown in horizontal drilling in the need to navigate the reservoir as it is drilled. Mostly in the early stages of the oil field's development, the reservoir may not always be found as forecast and as a result a well of about US$ 20 million may be lost. One of the challenges is to explore the use of optic fibre cables, connected to a VRC, to monitor the real-time drilling to make sure the rig will hit its target and will not skip the reservoir [Petrobras99]. This application obviously requires real-time features of the virtual reality system, as usually rig information is sent from the field at regular time intervals.

2.2 Design and Construction Phase

During the design phase, the oil & gas industry is interested in visualizing offshore structures, performing static and dynamic simulations of these structures to ensure their stability, examining the construction processes, analysing procedures for monitoring oil pipelines and emergency situations etc. The construction phase will only be executed, once these issues are fully analysed to the satisfaction of all the stakeholders.

2.2.1 Reviewing the construction process

Offshore structures, modelled using CAD systems, have every single component highly detailed, since the goal here is to analyse the construction process.

The engineers need not only to have access to every single part of the model and its characteristics, but also to review the model from different perspectives. Therefore the key challenge in this process is to develop a dynamic virtual environment to allow the designers to assess the construction of the offshore structures from their own perspectives. This will require a flexible software framework which can provide access to various simulations with personalised interfaces.

The installation of subsea equipments is a challenging task during the construction of offshore structures, requiring precise manipulation inside a complex environment. This requires highly skilled people to ensure the operations can be done efficiently without damaging the surrounding equipments. The challenge here is to enhance the current capabilities of the VR technology to allow engineers to rehearse such intricate operations in advance to avoid costly mistakes. The use of robots is also being investigated to conduct such operations remotely.

2.2.2 Stability analysis

Thorough analysis of stability of the offshore structures is an important aspect to be considered during the design phase, where thousands of barrels of oil are produced daily in the open sea. The stability analysis needs to take into account the stress conditions, sea currents, waves and wind pressures on semi-submersible platforms and FPSOs (Floating Production, Storage and Offloading unit). Additionally, these production units may be floating in the sea, which is more than two thousand meters deep, and therefore requiring the deployment of complex mooring systems.

Most of the current simulators are still static [Coelho03], but the demand for dynamic simulations is growing in the oil & gas industry to conduct rich simulation of offshore structures to ensure safe operation. Examples of such dynamic simulators are Dynasim [Coelho01] and NOT (Numerical Offshore Tank) from Petrobras. The Dynasim system has been designed to compute the supervening forces and consequential movements on anchored structures, where as NOT has been designed to simulate waves, currents, the line dynamics and the damping of floating production and storage oil & gas systems. The key challenge which is being explored in this work is the deployment of massively parallel computing with PC clusters to support interactive visualisation and simulation. Another key challenge in this area is the deployment of such dynamic simulations to give designers and engineers the feeling of the movements suffered by the unit, using hardware simulators. Such a simulator could be used for assessing various issues in operation, maintenance and emergency scenarios.

2.3 Production Phase

The main aim of this phase is to support efficient and safe production of oil & gas. This requires putting in place a well trained work force for operation, plant monitoring, maintenance, emergency handling etc. This section discusses how virtual reality technology could be used for supporting these key activities.

However, the application of VR in this phase requires an up to date virtual model of the plant. As a result, any changes to the plant need to be captured and be used to maintain a valid virtual representation of the real plant. This could be done by means of a 3D laser scanner that is capable of acquiring a cloud of points from the real structure. This section describes few examples to illustrate the use of VR in the production phase.

2.3.1 Monitoring

During the production phase, the virtual reality technology has the potential for supporting better monitoring of plants. Examples of such monitoring tasks include remote monitoring of oil pipelines to avoid oil spillages, stability of the offshore structures and off loading operations.

To better analyse oil pipeline deformations, it is possible to use post-videos over the structural analysis results. Also the manager or the specialist could be allowed to receive a visual representation of the oil pipeline directly from the field, in case of an accident or during a maintenance operation. However, in order to transmit data from the field to the expert's virtual workspace, the equipments used by the field engineers must not be heavy and should be based on mobile technology to work on difficult terrain conditions.

2.3.2 Emergency scenario

The importance of rigorous procedures for handling emergency situation is now becoming extremely important due to ever growing environmental concerns. An oil spillage could have a devastating consequence on the environment costing millions of dollars to constrain the damage. Virtual reality can play a significant role in developing systems for training people for handling such situations and also for connecting experts during such a disaster situation to advise the workers, on the ground, to control the situation.

One such system, which has been developed to manage and control actions during a leakage of a pipeline is InfoPAE [Carvalho02]. It provides facilities to manage conventional and geographical data, associating them with the plans. The system has been developed to help and minimise the response time, to validate and optimise the emergency plan's logic and to train the teams responsible for the actions.

Another typical emergency scenario in the oil & gas area is a crisis situation in an offshore structure, when the structure becomes unstable. In this scenario, there are two main possibilities:

- If the unit is heavily damaged and has security problems, then the unit is abandoned and no person remains inside the offshore platform. In such a situation, divers are called to do possible rescue operations.
- If the unit has a minimal security condition, it usually remains with two or three operators. In such a situation, operators receive instructions from the experts on the ground to stabilise the offshore structure.

During such emergency situations, several expertises are brought together to provide advise. Typically the specialists involved are naval engineers, structural engineers, risers analysts and oceanographers. These specialists are geographically distributed and therefore in need of an efficient IT environment to support the collaborative decision making process.

3. CLASSES OF WORKSPACE CHALLENGES

In order to develop usable industrial solutions, it is important to first identify and analyse the industrial processes and the requirements and expectations from the specialists. Such an analysis for the oil & gas industry was presented in Section 2 in this paper.

From this analysis, it is apparent that the oil & gas industry needs a suit of virtual workspaces for supporting various tasks such as seismic exploration, design reviews including dynamic simulation of offshore structures, training environments for subsea offshore equipment installation and disaster management, monitoring of real-time follow-up and correction of the course of a deepwater horizontal well, decision making environment for emergency situations, monitoring environments for oil pipelines, offshore structures and off loading operations etc. When constructing virtual workspaces for these applications, great care must be given to the user's expectations, appropriate collaboration operations, interaction metaphors, appropriate display environments and visualisation techniques to suit the tasks and the expert teams. Since most of these workspaces will be used by multi functional teams, it is important to deal with different levels of perception and perspectives that users are expecting to conduct their tasks. The VR technology used for building such workspaces should fit the user in terms of intuition, attention and productivity [Parkin99].

Although each application requires specific functionality and interfaces, the following generic classes of virtual workspaces, for the oil & gas industry, can be identified from the analysis given in Section 2:

- Distributed Design Review Workspaces.
- Co-located Design Review Workspaces.
- Field Activity Monitoring Workspaces.
- Disaster Management Workspaces.
- Training Workspaces.

The following subsections discuss the generic technology challenges faced when building these generic and specific workspaces.

3.1 Real-time Visualization and Interaction

A common characteristic of a typical virtual workspace, constructed for supporting an E&P process, is the enormous amount of data it has to deal with. The type of data could vary from seismic data for reservoir exploration to CAD and simulation data for the design and construction of offshore structures. For tasks such as monitoring of oil pipelines over a mountain, GIS, CAD and video data need to be brought together to support the construction of the monitoring virtual workspaces. Such scenes could be out door environments or complex structures (offshore structures) with different spatial characteristics. Furthermore, the data produced for supporting certain design functionality may not have an efficient representation for achieving the best visualisation performance, requiring certain pre-processing techniques.

The challenge here is how to decide what part of the data to visualize at each time. This is not only because of performance and real-time constraints but also to avoid cluttering the scene with unnecessary data. Therefore model simplification algorithms which do not eliminate key features of the structures are important to provide usable real-time visualisation services for E&P processes. In addition, real-time performance for visualising such large data sets needs to be gained by utilising the power of specialised hardware solutions or PC clusters.

In these virtual workspaces, the construction of interfaces for supporting specific activities for specific experts is extremely important to achieve user acceptance of the technology. Such interfaces need to be natural and simple without requiring any training. Although some advanced interaction technologies are now becoming available, it is important to research and build simple interfaces appropriate for a task. In [Froehlich99], Froehlich claims that the geoscientists found the Cubic Mouse, an input device specially tailored to geo-scientific data, is very natural and effectively performs their tasks. Its interesting characteristics are the sensation it gives the user of having the whole model in his hand and the possibility of easily moving through 2D slices of the model by simply sliding small bars of the cube. It allows the users to focus on their exploration tasks rather than on operating the computer. Further research is required to identify interface devices and paradigms for supporting natural interaction within E&P virtual workspaces.

3.2 Collaboration

One of the most important challenges in constructing oil & gas E&P virtual workspaces is the development of efficient collaborative virtual environments (CVE). This is because most of the projects involve many professionals who are geographically dispersed over a country or even across different countries, who need to work together as a virtual team. These cross-functional team members need to collaborate effectively and make decisions quickly and accurately to support various stages of the E&P process.

3.2.1 Distribution support

For a virtual environment to be collaborative, it must be distributed between the participants who wish to share it. The choice between communication architectures is parameterized by the degree to which the data structures representing the virtual environment are replicated or cached between the computing nodes and the underlying transportation technology [West01].

However, whatever the technology, communication latencies are an important factor in building usable collaborative systems. If it is not possible to achieve the adequate synchrony, one solution is to at least focus resources upon those activities which are most sensitive to lag, i.e. those which produce the most pronounced discontinuities of perceptual experience when lag is present. For the moment, it is fair to say that there is no universal choice of distribution or communication architecture, but rather a range of trade-offs in performance and deployment issues [Singhal99].

It is impossible to predict the network requirements of CVEs in isolation; rather, we need a model of CVE operation which encompasses the application, user, software and hardware concerns. In this paper we follow the model proposed by Greenhalgh [Greenhalgh01], which has six layers:

1. Task/application/collaboration requirements: what do people want or try to do? For each virtual workspace, it is important to identify the exploration or design tasks that the user is expecting to perform.
2. User behaviour: what particular actions do people do and when? For example, if users speak only rarely, and never at the same time, then the network requirement for audio could be very limited. On the other hand, for some scenarios, there must be enough bandwidth for every user to speak at the same time. This could be the case of the emergency scenario, for example.
3. Process behaviour: how does the application respond? Once again, the emergency scenario could be a good example: while people heading the whole operation could execute any command, the other specialists could only execute the tasks they were asked to.
4. Distribution architecture: what communicates with what? The choice of distribution architecture determines which information must be communicated to which parts of the system. Typically, communication will be necessary between both people and simulators. Typically oil & gas applications nowadays are held in no more than a half dozen visualization rooms simultaneously, with no more than 20 specialists in each one. In the case of dynamic simulation of offshore structures, simulators performing various analyses need to communicate their data to each other and/or to a central controller to produce the final results of the simulation.
5. Communication protocols: how is information exchanged? Protocols can be either unicast or multicast or a combination to achieve both performance and reliability.
6. Network communication: what actually happens in the network? In the particular case of oil & gas applications, as presented in Section 2, it is not unusual to have one or more specialists out in the field who need to be somehow connected to the collaboration environment. This could be done by a mobile system. Therefore it is important to support both fixed and mobile communication for E&P workspaces.

Due to the high commercial value of their data, oil & gas industry has imposed strict data base consistency and security requirements. As a result, the data is typically at various sources which need to be brought together to support innovative virtual workspace concepts discussed in this paper. The grid concept seems to match those requirements, since it is conceptually centralized with real data, distributed at various places transparently to the application.

3.2.2 Collaboration metaphors

While it is important to develop a flexible and open software platform for supporting collaboration, the human factors issues for supporting tighter interaction between the team members should not be ignored. Due to space limitations, only few interaction considerations important for supporting collaborative working within the E&P workspaces are summarised below:

- In some cases, experts would need the possibility of having a copy of the data model in their private workspaces to explore their ideas individually, and to take their views to the shared workspace for discussion. Such a facility is important for applications such as modelling or interpreting an oil reservoir or dealing with an emergency scenario.
- During collaborative discussions or training, it is important to control and share various viewing points to communicate ideas to each other. Some key viewing support necessary within collaborative working could be summarised as: (i) sharing of each other's viewing point (look over the other's shoulder) [Cheng98]; (ii) mirrored viewing point (the opposite side of the situation). Furthermore, in some emergency training situations, the trainees may want to observe the simulation result from various view points in parallel. For example, one might want to observe the simulation effect of a possible emergency operation using an exocentric point-of-view (outside in) and another may want to observe the simulation effect using an egocentric point-of-view (inside out). Such parallel observation could lead to better understanding of the emergency situation and to work learn to as a team.

The next generation of collaborative workspaces will provide much more realistic face-to-face tele-immersive environments, integrated with appropriate simulations and data bases [Johnson01]. Such mixed-reality workspaces, created by combining virtual workspaces and video avatars of users, have the potential for mimicking co-located meeting metaphors. However, the human factors issues, performance issues and business benefits of such environments will need to be addressed properly to ensure their acceptance by the oil & gas industry.

4. CONCLUSIONS

This paper discussed E&P processes of the oil & gas industry with the view to identifying how VR technology can be used to build better virtual workspaces for these processes. Several generic virtual workspaces were identified which are specific for the oil & gas industry. Finally the paper presented some of the generic technology challenges in building virtual workspaces for the oil & gas industry.

This paper emphasised the need for developing virtual workspaces with a thorough understanding of the processes and the user expectations to ensure their acceptance by the oil & gas industry. Furthermore, the paper argued that the interfaces of these virtual workspaces need to be mapped onto the roles and the tasks of the users.

However, the construction of virtual workspaces for every possible application and various users can be a tedious and expensive task. Therefore it is important that future research lays foundation for creating reconfigure-able and dynamic software architectures to facilitate easy construction of various virtual workspaces on demand.

5. ACKNOWLEDGEMENTS

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Emergency Environments for the Oil & Gas Exploration and Production Industry

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Abstract:

The objective of this poster is to present some of the key challenges faced when defining and building virtual workspaces for oil & gas Exploration & Production (E&P) activities, such as 3D geomodelling, seismic interpretation, real-time drilling follow-up and correction, offshore structures' design, static and dynamic simulations of these offshore structures, oil pipelines' monitoring and emergency situations' handling. Also a case study focusing on emergency scenarios with extreme conditions is discussed in details.

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1. INTRODUCTION

The oil & gas industry has been a leading player in exploiting the power of virtual reality technology to enhance its business processes. The motivation for deploying such advanced technology in this industry is due to the difficulties that the companies were facing in the late nineties, with the price of oil hovering near all-time lows.

The Virtual Reality Centres (VRCs), large projection rooms with features such as 3D and stereoscopic images, soon became very popular in the oil & gas industry, since they gave specialists the ability to quickly and comprehensively interpret large volumes of data, thus significantly reducing cycle time for prospect generation [American98].

Petrobras built the first Latin America VRC in its R&D centre (CENPES) in 1998. The idea was to test moderate-priced configurations, show the benefits of this technology and encourage the installation of similar VRCs at other operational units of Petrobras.

Another VRC was built in the company's headquarters in 1999 and now Petrobras has already ten VRCs being used all over the country, including a holo-space installed in its headquarters.

However, due to ever increasing business pressures, there are further demands on researchers to extend the capabilities of the VR technologies, so that it can be fully utilised in all the oil & gas exploration and production (E&P) phases.

2. TYPES OF E&P PROCESSES

This section discusses the main processes of the oil & gas E&P industry and the main challenges within each process. The work presented here is based on the authors' experience with oil & gas projects at Petrobras in Brazil.

2.1 Reservoir Exploration Phase

During this exploration phase, the goal is to elaborate the subsurface models that best represent the reservoirs. Whether it is a seismic cube or a stratigraphic geological model, what is important in this phase is to build an individual mental representation of the model. Therefore the key tasks in this phase are 3D geomodelling and 3D seismic interpretation.

2.1.1 3D geomodelling

3D geomodelling involves a large spectrum of skills, spread over different domains (geophysics, geology, reservoir and petroleum engineering). During its lifetime, a numerical earth model is shared by people with different types of specializations. The model evolves continuously over time, by absorbing various inputs from the team members [Reis01], as shown in Figure 1.

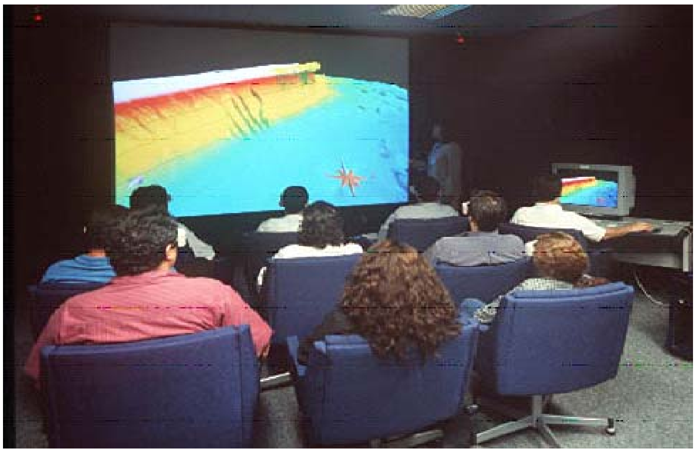

Figure 1: Team members discussing a 3D geological model.

The main software that have been used in 3D geomodelling until now include GOCAD, Landmark, Schlumberger and Earth Vision from Dynamic Graphics. Petrobras is already using synchronized viewing of the earth model among different specialists.

2.1.2 3D seismic interpretation

The advent of VRCs and stereoscopic images opened a door to a new world for seismic interpretation, allowing the users to visualise and explore in an interactive manner. The work became much more easier since specialists no longer need to use their knowledge and imagination to draw a mental picture of the area and to feel immersed in it. A mapping that used to take months began to be drawn in just a few hours [Petrobras99].

In terms of software, several geophysical visualisation programs have been developed, namely, in-depth Reverse Time Migration, 2D and 3D acoustic and elastic seismic modelling, and seismic volume visualisation [Silva03], such as the one seen in Figure 2.

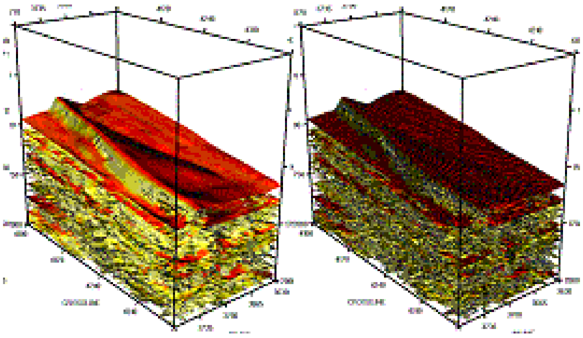

Figure 2: Seismic volume visualization with different methods.

2.1.3 Real-time follow-up and correction of the course of a deepwater horizontal well

Mostly in the early stages of the oil field's development, the reservoir may not always be found as forecast and as a result a well of about US$ 20 million may be lost. One of the challenges is to explore the use of optic fibre cables, connected to a VRC, to monitor the real-time drilling to make sure the rig will hit its target and will not skip the reservoir [Petrobras99].

Petrobras is already using this technology in the exploration phase, including an in house development known as gWLog [Campos02].

2.2 Design and Construction Phase

During the design phase, the oil & gas industry is interested in visualising offshore structures, performing static and dynamic simulations of these structures to ensure their stability, examining the construction processes, analysing procedures for monitoring oil pipelines and emergency situations etc.

2.2.1 Reviewing the construction process

The engineers need not only to have access to every single part of the model and its characteristics, but also to review the model from different perspectives.

When dealing with virtual reality applications over these types of data, the focus is in visualising and walking through the facility with good performance and sufficient realism. It is necessary to treat the data before visualising them.

For this purpose, many recent works have been developed searching for efficient solutions for the conversion of CAD models to VR models. An example is the ENVIRON tool [Corseuil04], shown in Figure 3.

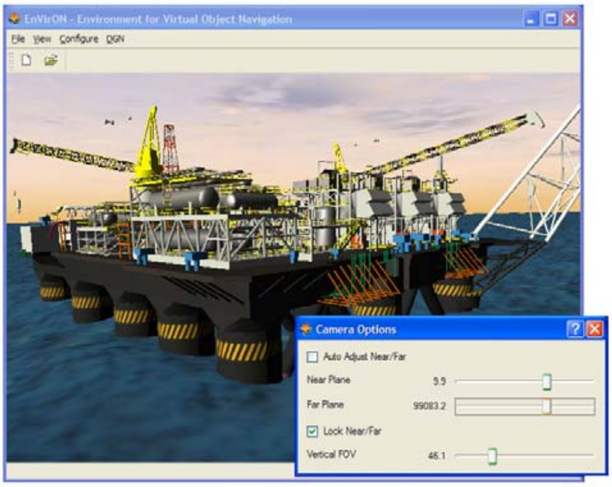

Figure 3: ENVIRON screenshot.

2.2.2 Stability analysis

The stability analysis needs to take into account the stress conditions, sea currents, waves and wind pressures on semi-submersible platforms and FPSOs (Floating Production, Storage and Offloading unit). Additionally, these production units may be floating in the sea, which is more than two thousand meters deep, and therefore requiring the deployment of complex mooring systems.

Most of the current simulators (Figure 4) are still static such as Sstab [Coelho03], but the demand for dynamic simulations is growing in the oil & gas industry to conduct rich simulation of offshore structures to ensure safe operation. Examples are Dynasim [Coelho01] and NOT (Numerical Offshore Tank) from Petrobras.

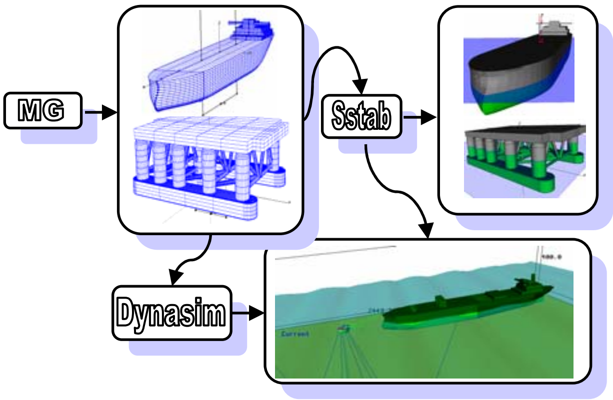

Figure 4: Integration among simulation tools.

2.3 Production Phase

The main aim of this phase is to support efficient and safe production of oil & gas. This requires putting in place a well trained work force for operation, plant monitoring, maintenance, emergency handling etc.

2.3.1 Monitoring

During the production phase, the virtual reality technology has the potential for supporting better monitoring of plants. Examples of such monitoring tasks include remote monitoring of oil pipelines (Figure 5) to avoid oil spillages, stability of the offshore structures and off loading operations, all of them already being employed by Petrobras.

Figure 5: Virtual pipeline trajectory over a satellite image.

To better analyse oil pipeline deformations, it is possible to use post-videos over the structural analysis results. Petrobras is also analysing solutions to allow the manager or the specialist to receive a visual representation of the oil pipeline directly from the field, in case of an accident or during a maintenance operation.

2.3.2 Emergency Scenarios

An oil spillage could have a devastating consequence on the environment costing millions of dollars to constrain the damage. Virtual reality can play a significant role in developing systems for training people for handling such situations and also for connecting experts during such a disaster situation to advise the workers, on the ground, to control the situation.

One such system, which has been developed to manage and control actions during a leakage of a pipeline is InfoPAE [Carvalho02], shown in Figure 6. It provides facilities to manage conventional and geographical data, associating them with the plans.

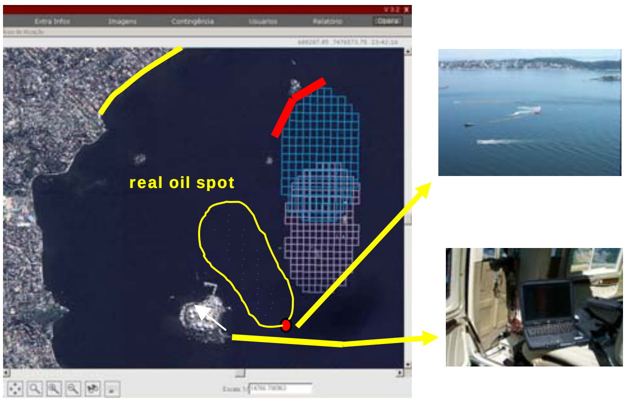

Figure 6: InfoPAE: emergency scenario application.

Another typical emergency scenario in the oil & gas area, described in the next section, is a crisis situation in an offshore structure, when the structure becomes unstable.

3. DISASTER MANAGEMENT OF OIL & GAS OFFSHORE STRUCTURES

Offshore units disasters can not only cause deaths and important environmental impacts, but also have a strong impact on business. Companies can lose billion of dollars by losing an offshore unit and further billions of dollars due to the cease of the oil production.

Petrobras faced two major accidents in the beginning of this decade. In 2001, the largest semi-submersible platform in the world P-36 (40 story-high, weighing 31,000 tons) sunk, killing 11 employees and ceasing a daily production of 84,000 barrels of oil and 1.3 million cubic meters of natural gas.

In 2002, the FPSO (Floating Production, Storage and Offloading) unit P-34 with a daily production of 35,000 barrels and a storage capacity of 58,000 m^3 of oil, weighting 62,000 tons, had a stability problem and almost sunk, immediately ceasing its operation. Fortunately at this time, Petrobras managed to rescue the unit without loss of lives.

Petrobras, as one of the oil & gas companies seeking to employ efficient processes and technologies to respond to such events, had taken important actions in order to ensure safety.

The implementation of such processes involves bringing together a large number of diverse and geographically distributed groups and resources to make appropriate decisions within a short period of time. Such groups are comprised of many technical experts and decision makers such as naval engineers, structural engineers, risers analysts and oceanographers, as well as managers.

The high-level decision group will operate from the operational unit headquarters. The technical staff, running various simulation programmes which take into account the waves, wind, currents and other forces on the unit, operates either from a base on earth near the disaster, from the company's headquarters and/or from various research centres.

These groups need an efficient communication media with the operators inside the unit, divers and security team, and perhaps with experts who are travelling to execute the rescue plan and work towards consensus.

Petrobras has an on going project to develop a distributed ICT environment for the technical groups to work as a virtual team to explore various simulation options and to communicate their results to the high-level decision makers (Figure 7). To achieve this aim, there are some actions involved:

- a survey is being conducted to identify the requirements for the distributed workspace, from the stakeholders involved in a disaster scenario;
- a distributed workspace environment is being designed and built for the technical team to engage in the rescue efforts;
- the usability and functionality of this environment will be evaluated for training and operational purposes.

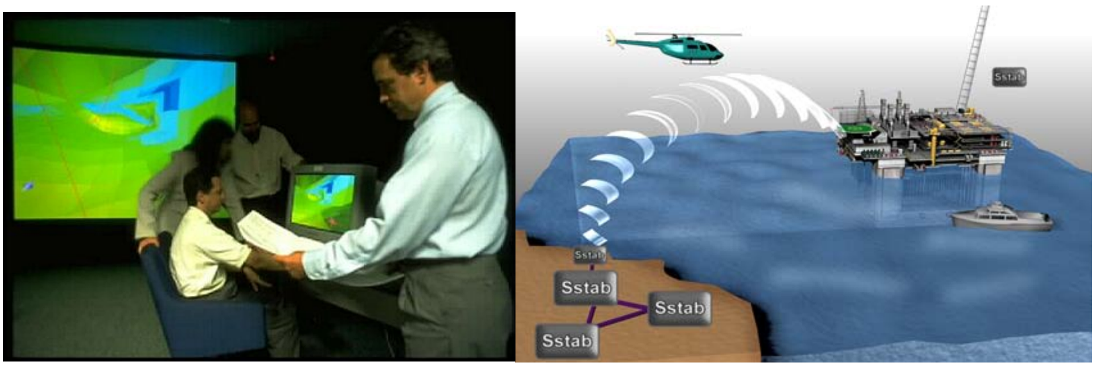

Figure 7: Emergency oil & gas E & P scenario with distributed people and resources.

4. ACKNOWLEDGEMENTS

The authors would like to thank Petrobras, Tecgraf/PUC-Rio and The University of Salford for their support, and, for their great contribution, Petrobras' engineers Álvaro Maia and Isaias Masetti, and engineer Luiz Cristovão Gomes Coelho from PUC-Rio.

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Apêndice C: Telas do Protótipo HLA

Neste Apêndice, apresentamos algumas telas mostrando a execução do nosso protótipo HLA.

Na Figura 24, podemos ver a sessão colaborativa sendo iniciada. Ela possui sete janelas contíguas representando, respectivamente, de cima para baixo: *(i)* no lado esquerdo, o servidor *Executive*, o Piloto da Emergência T0, o operador do SSTAB T1 e a Imprensa P1 (*Press*); *(ii)* no lado direito, o agente de software S2 executando o simulador WAMIT, o operador do DYNASIM T3 e o Tomador de Decisões DM1 (*Decision Maker*). Deve ser observado que cada um desses participantes poderia estar utilizando diferentes máquinas, mas eles estão utilizando a mesma máquina neste exemplo apenas para mostrar a sessão colaborativa na mesma tela. As Figuras 25 a 45 mostram, em ordem cronológica, a seqüência de telas da execução do protótipo.

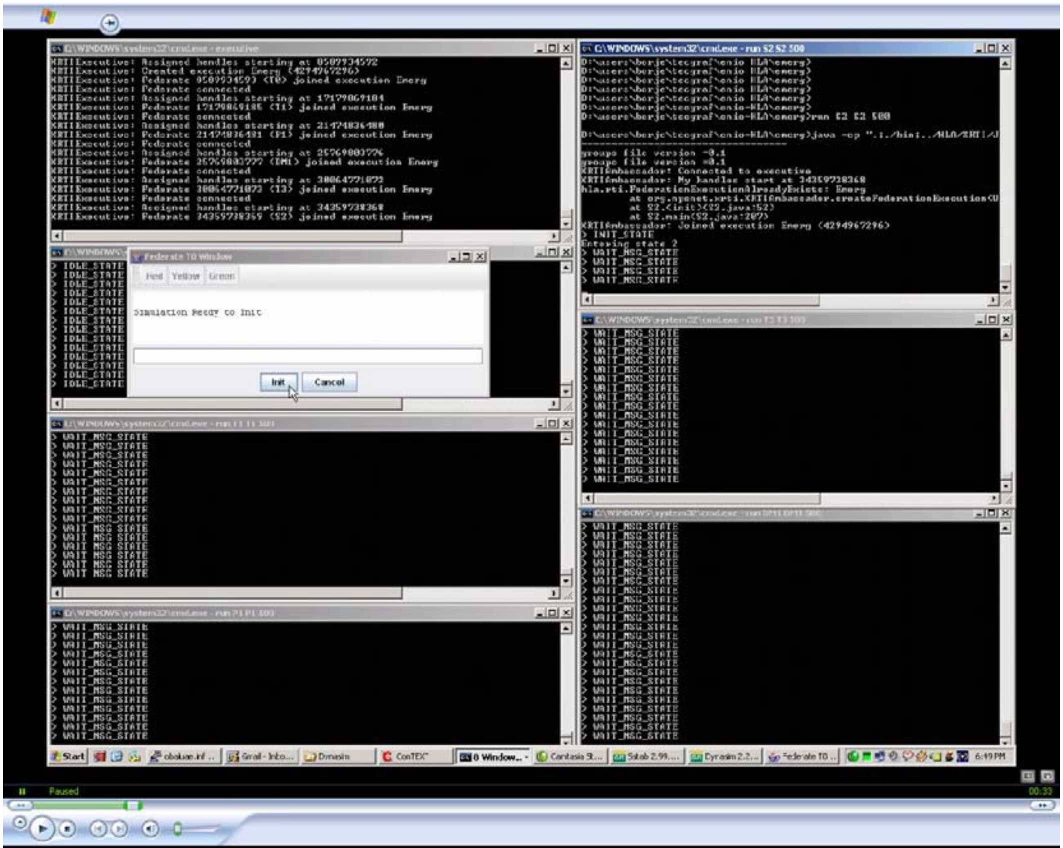

Figura 24 - Sessão colaborativa sendo iniciada

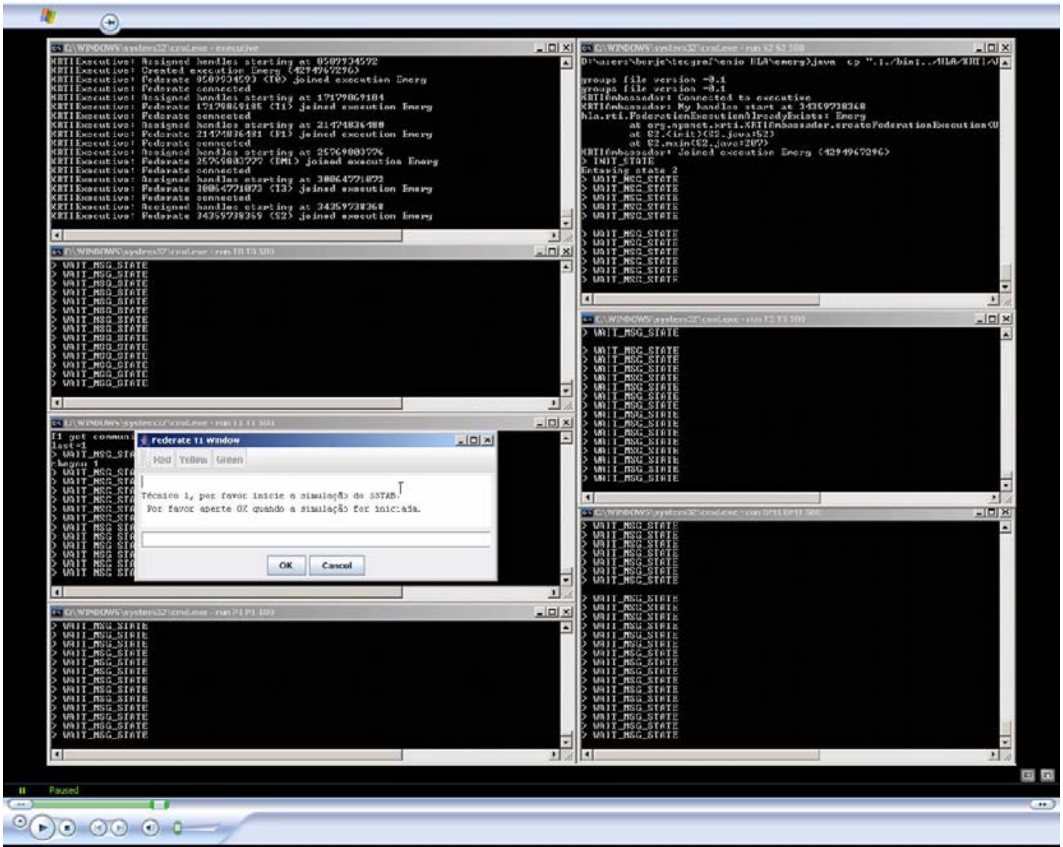

Figura 25 - O operador do SSTAB T1 recebe uma mensagem de T0 para iniciar a simulação do SSTAB

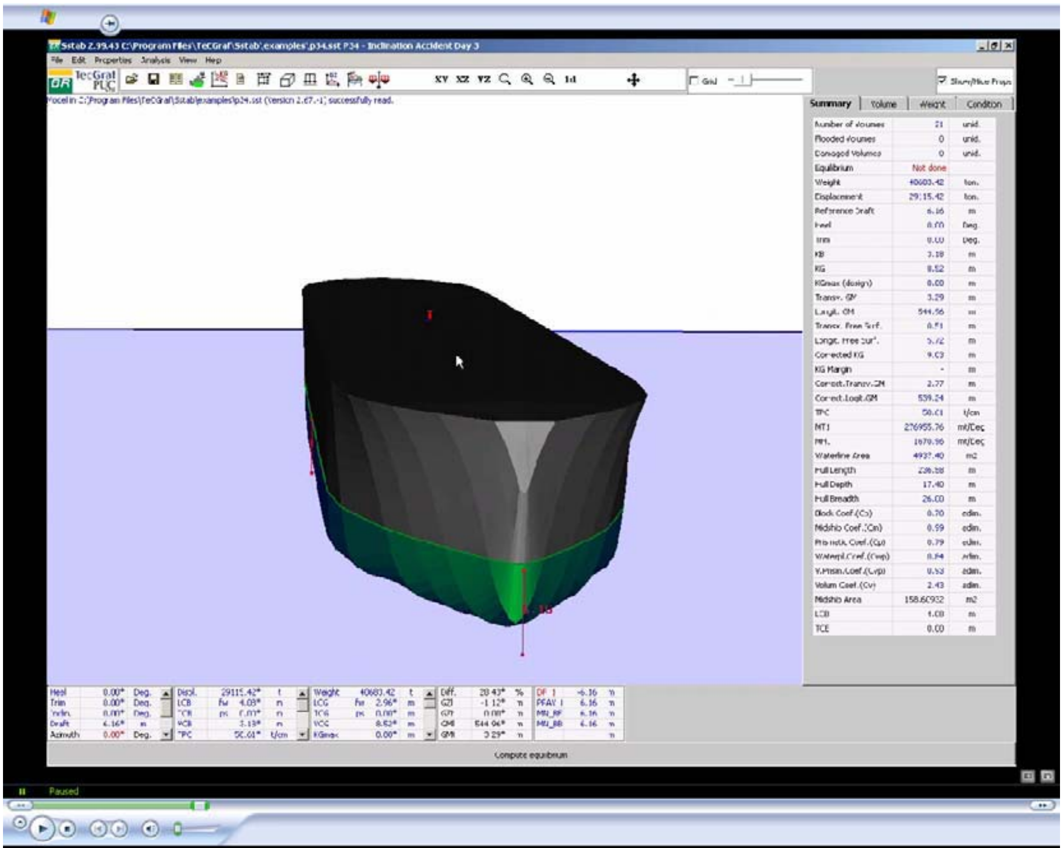

Figura 26 - O operador do SSTAB T1 inicia a simulação do SSTAB

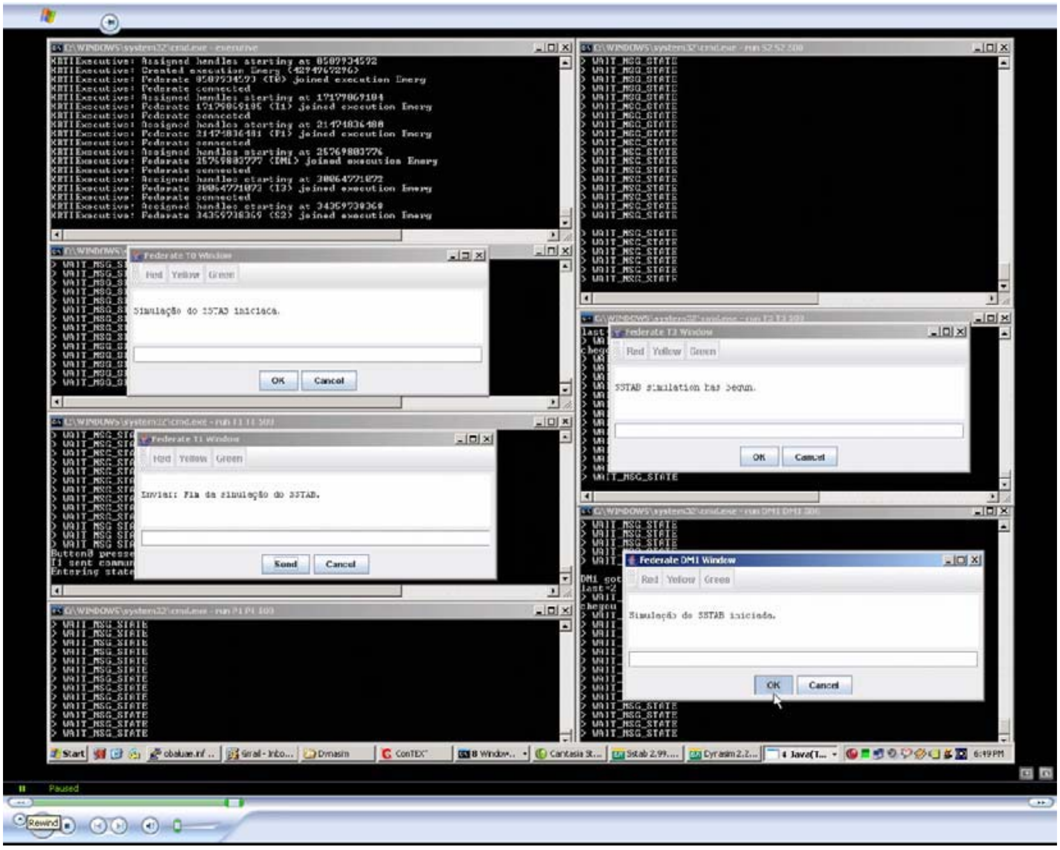

Figura 27 - Os federados T0, T3 e DM1 recebem uma mensagem de T1 informando que ele começou a simulação do SSTAB

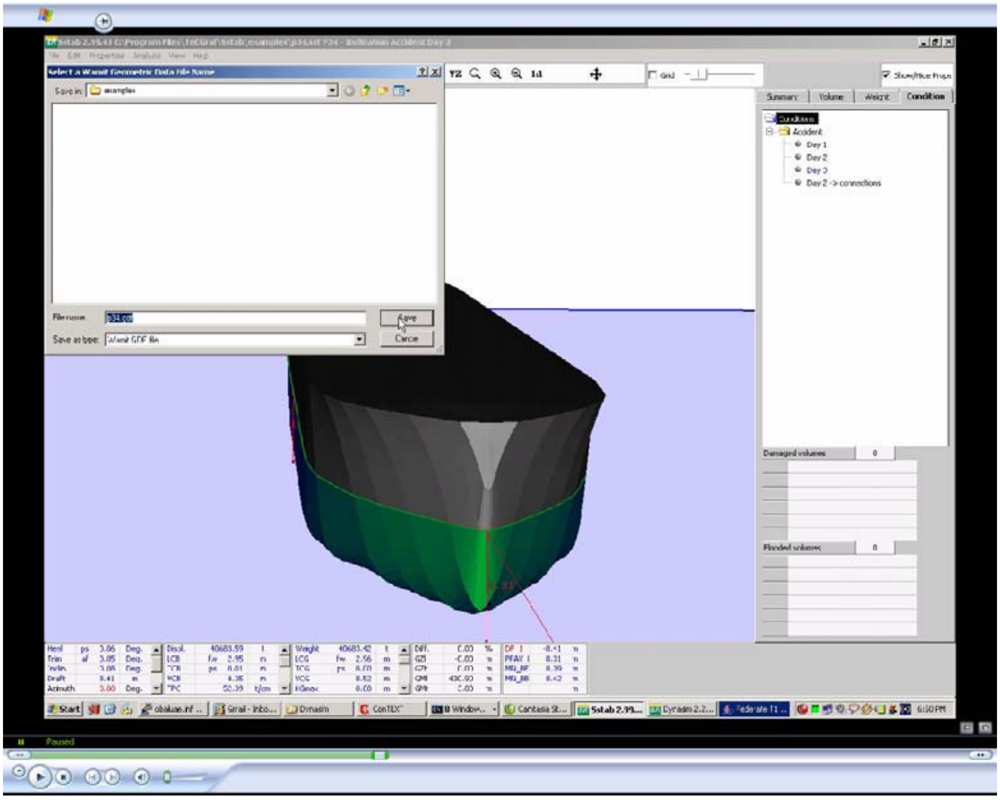

Figura 28 - T1 exporta um arquivo geométrico do WAMIT e termina a simulação do SSTAB

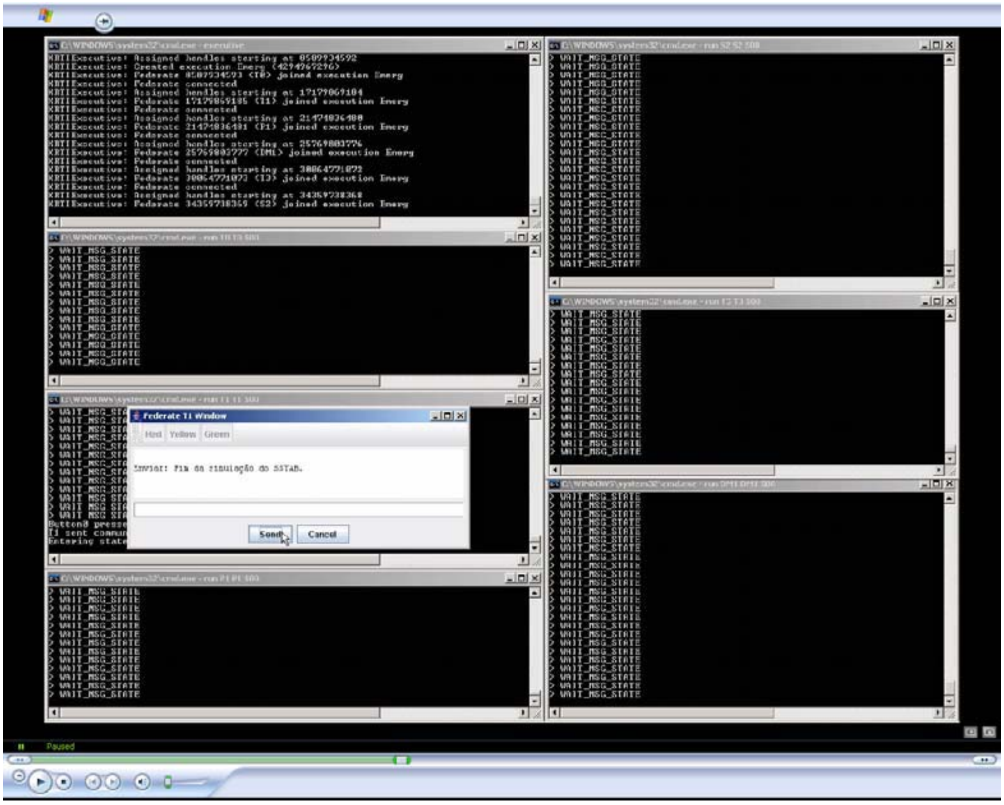

Figura 29 - T1 envia uma mensagem informando o fim da simulação do SSTAB, com S2 ativando automaticamente o simulador WAMIT

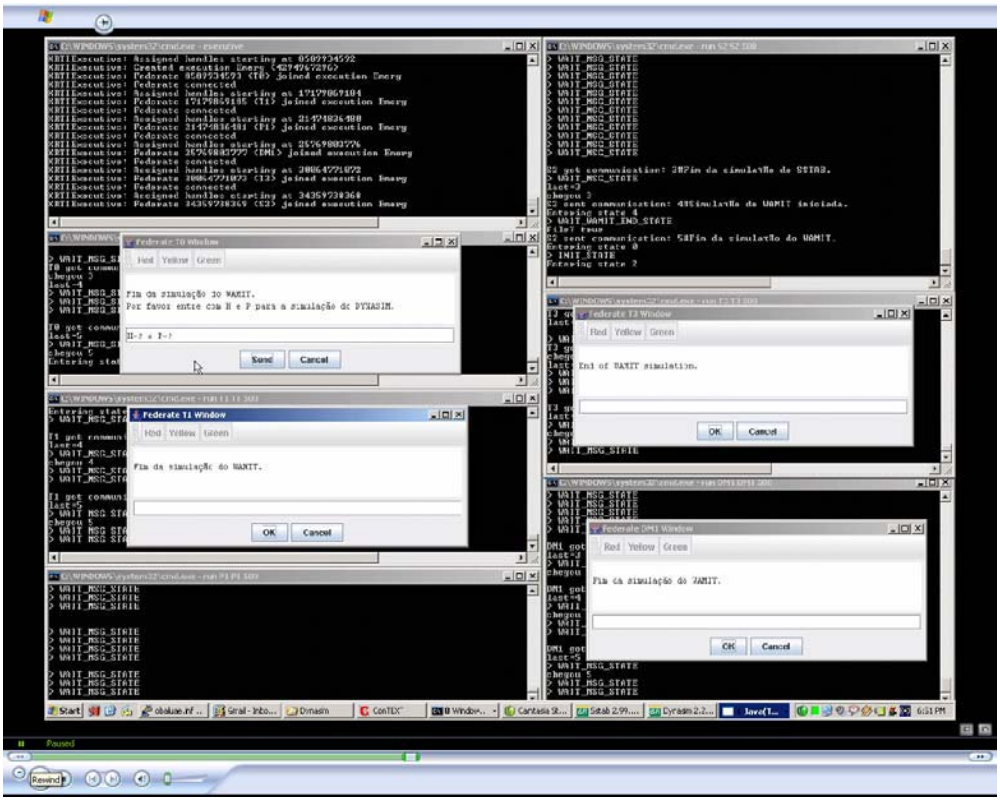

Figura 30 - S2 envia automaticamente para os federados T0, T1, T3 e DM1 uma mensagem informando o fim da simulação do WAMIT

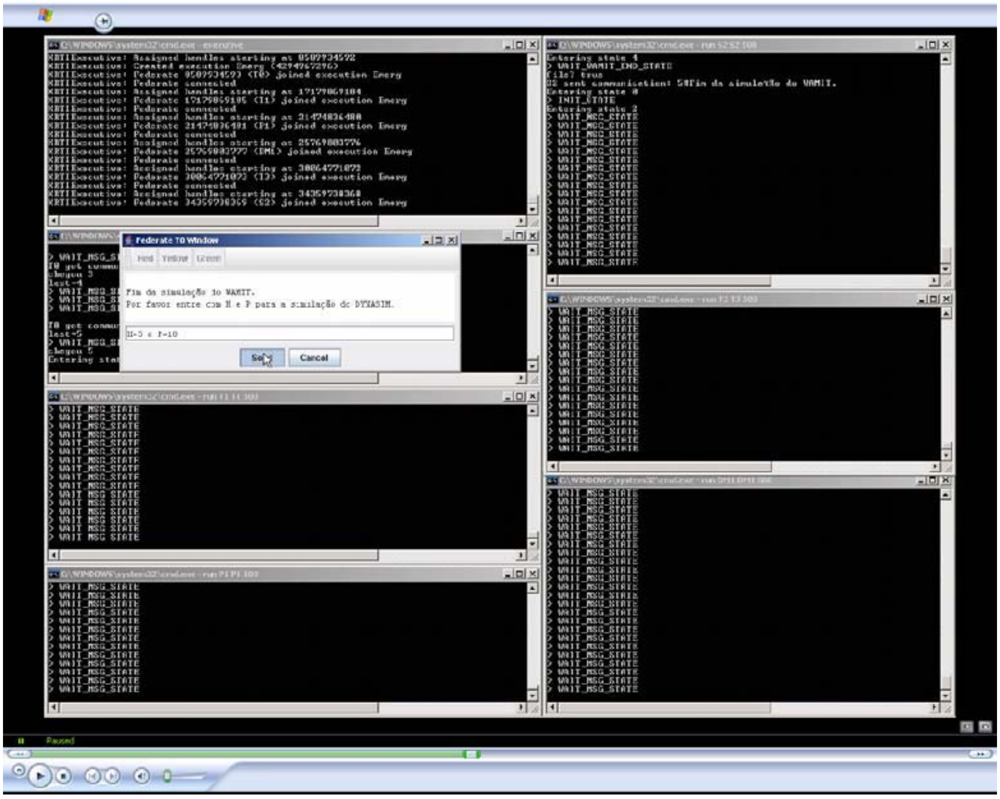

Figura 31 - O Piloto da Emergência T0 envia os dados ambientais (H=5 e P=10) para o operador do DYNASIM T3

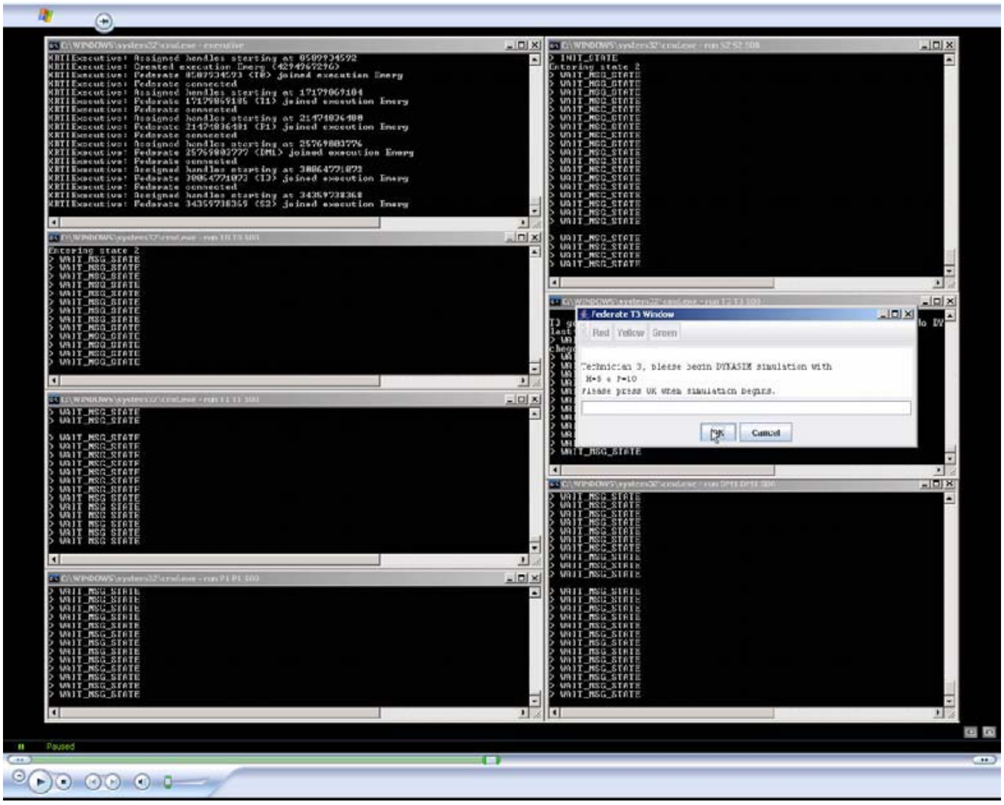

Figura 32 - O operador do DYNASIM T3 recebe os dados ambientais (H=5 e P=10) de T0

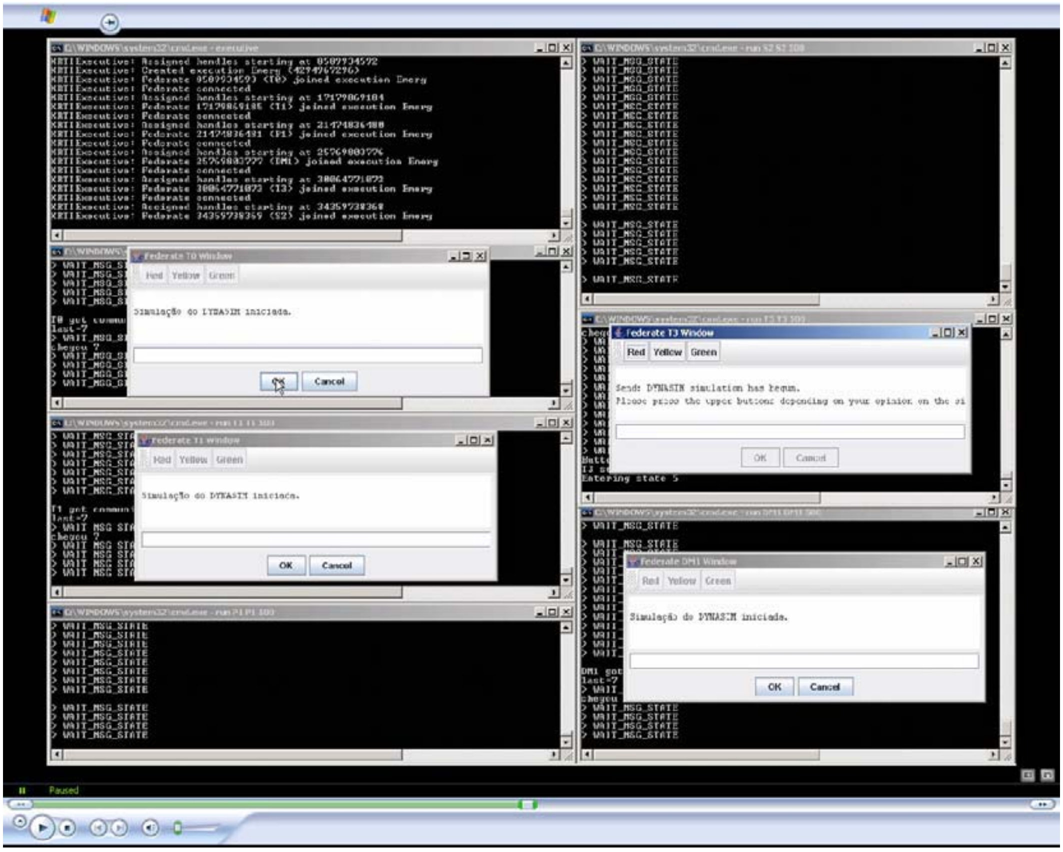

Figura 33 - O operador do DYNASIM T3 envia uma mensagem informando que ele irá iniciar a simulação do DYNASIM

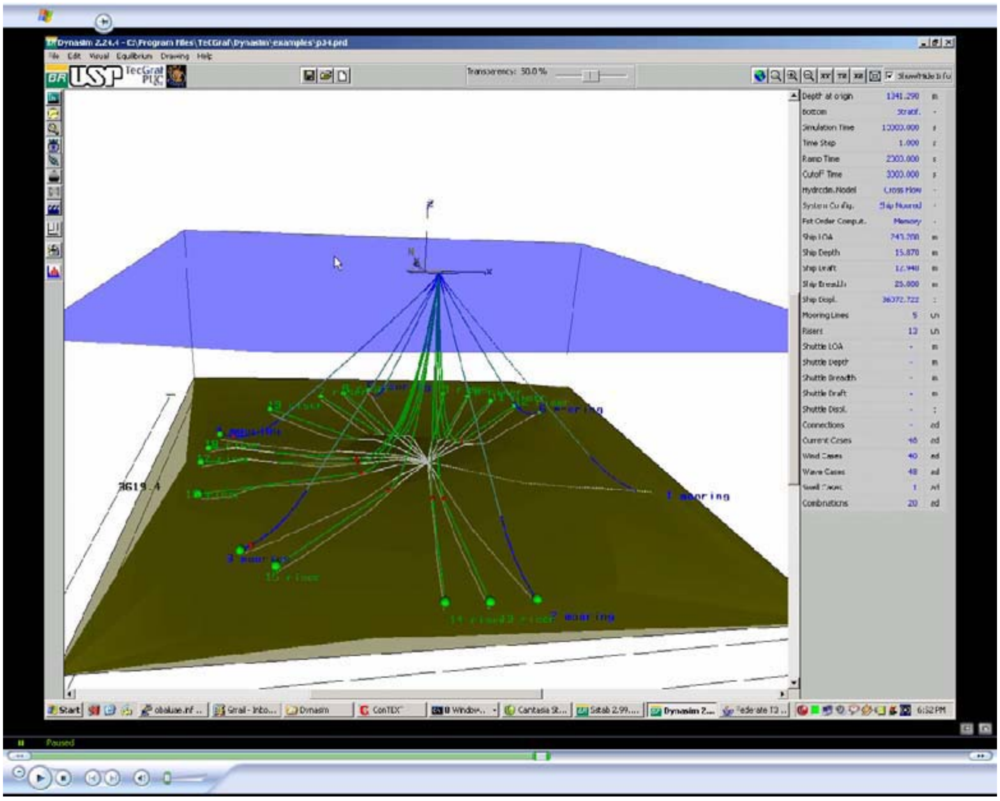

Figura 34 - A simulação do DYNASIM é iniciada

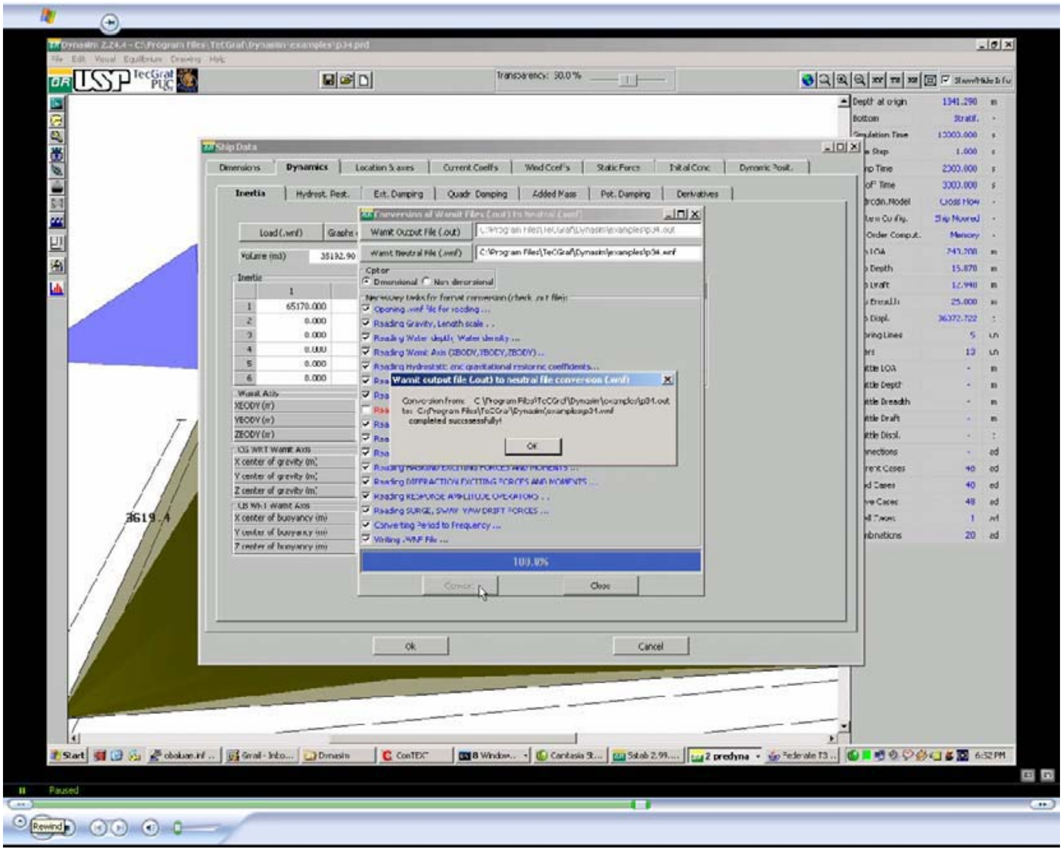

Figura 35 - O DYNASIM lê e converte o arquivo de saída do WAMIT em um arquivo neutro do WAMIT

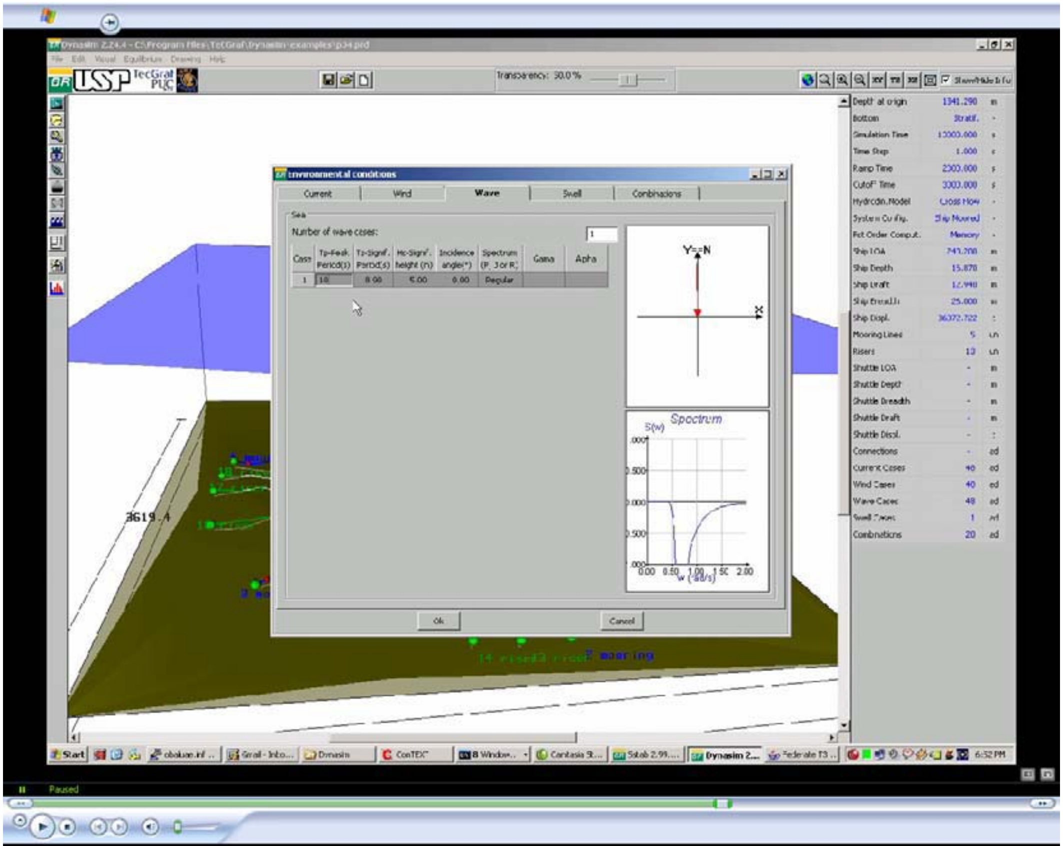

Figura 36 - T3 entra com os dados ambientais (H=5 e P=10) dentro do DYNASIM

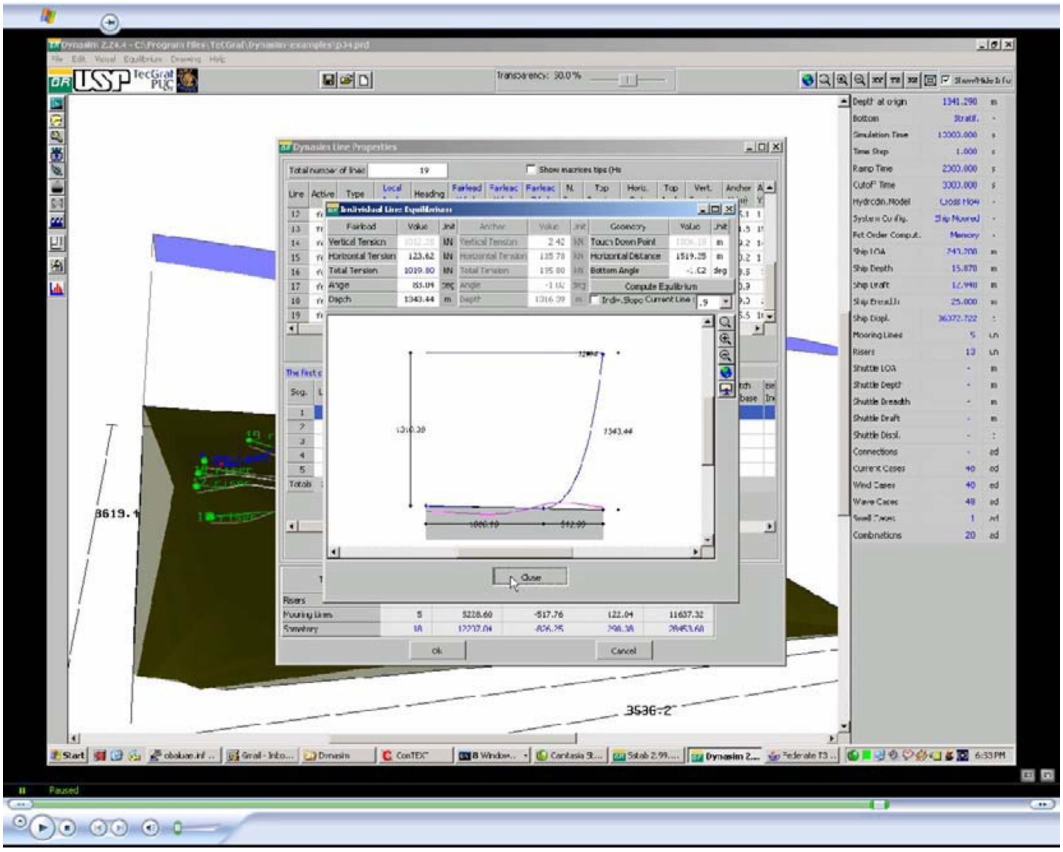

Figura 37 - T3 termina a simulação do DYNASIM

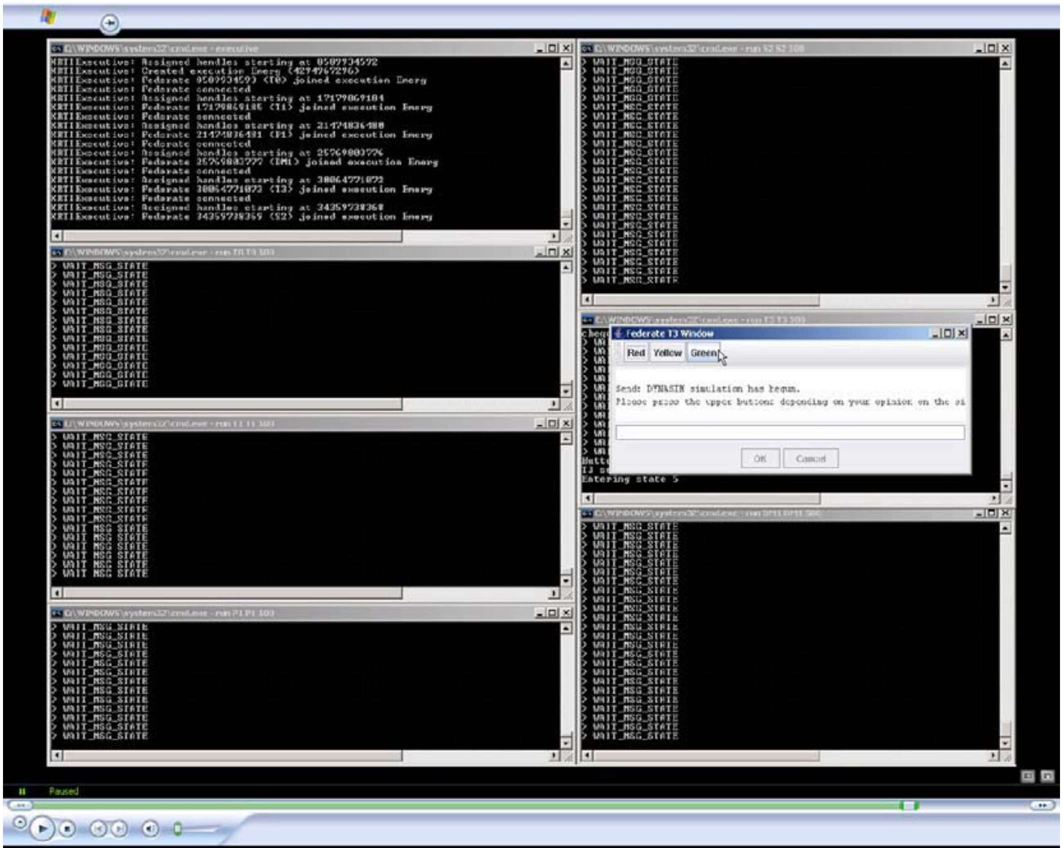

Figura 38 - T3 envia um sinal verde referente à simulação do DYNASIM

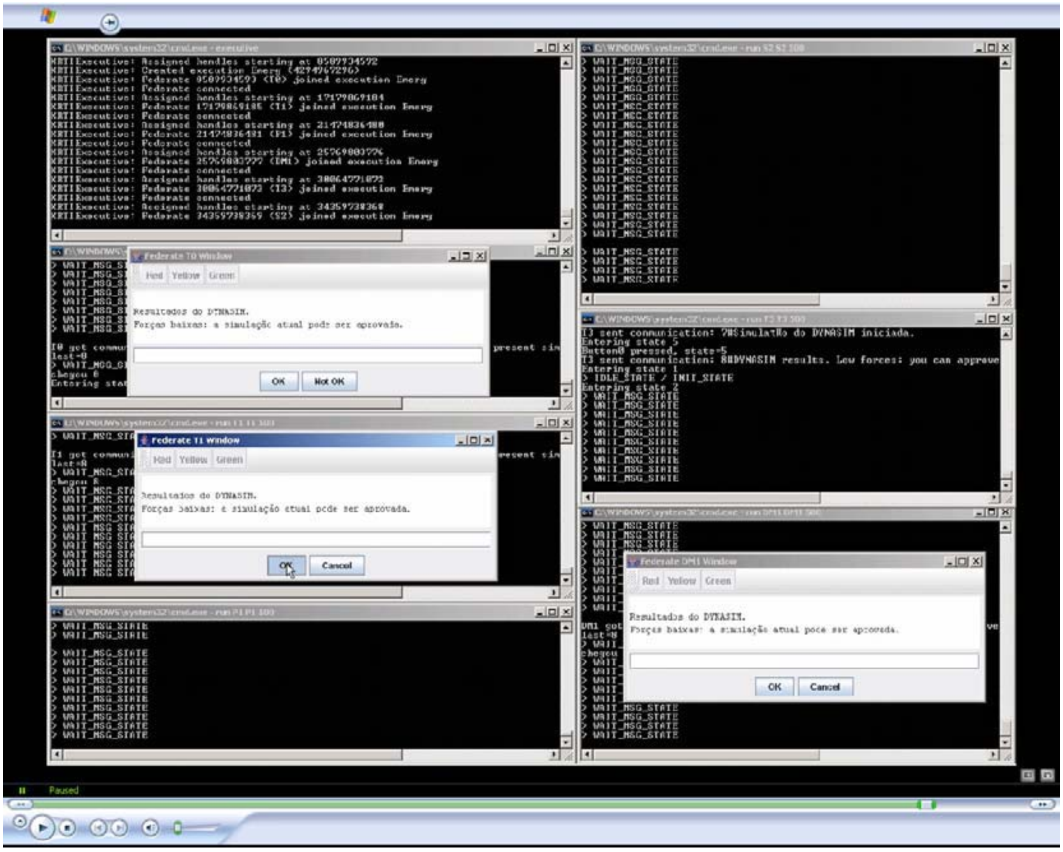

Figura 39 - Os federados T0, T1 e DM1 recebem uma mensagem de T3 informando o resultado da simulação do DYNASIM

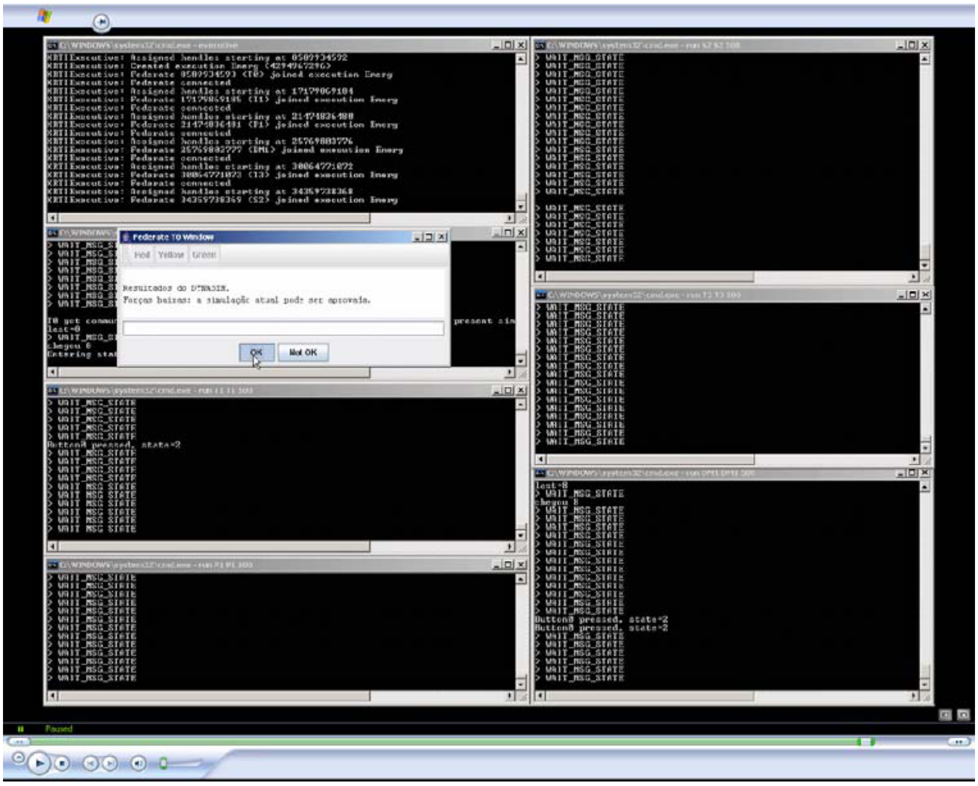

Figura 40 - O Piloto da Emergência T0 aprova os resultados das simulações

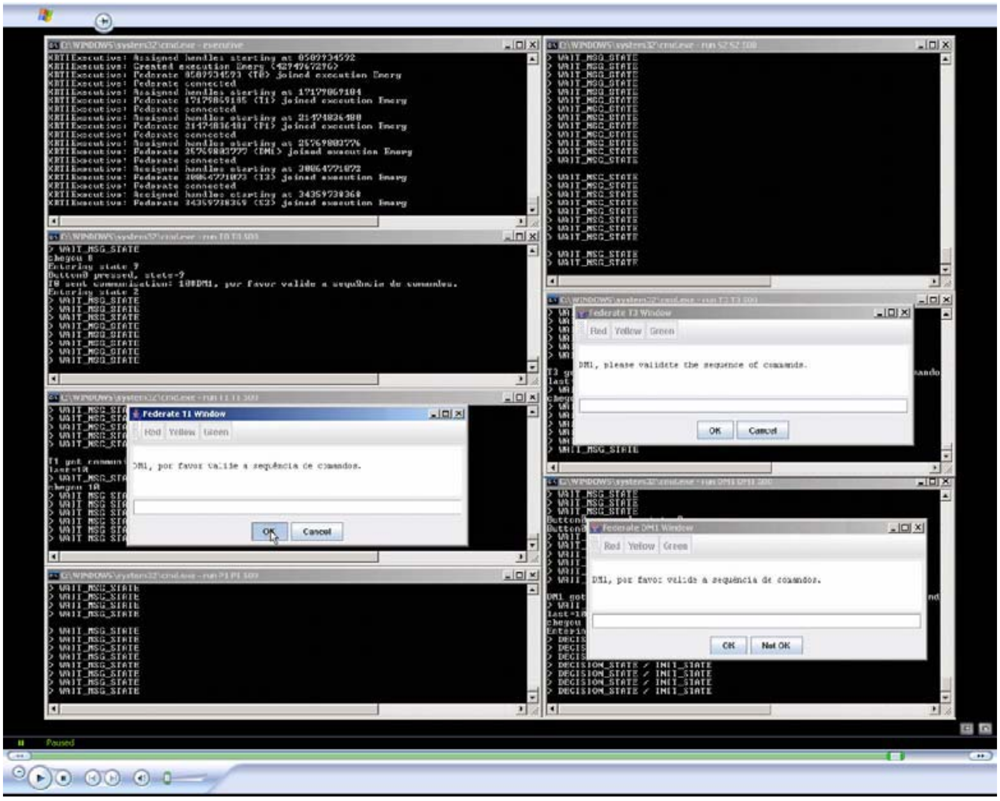

Figura 41 - O Tomador de Decisões DM1 (e os federados T1 e T3) recebe uma mensagem de T0 solicitando que ele valide a seqüência de comandos a ser executada

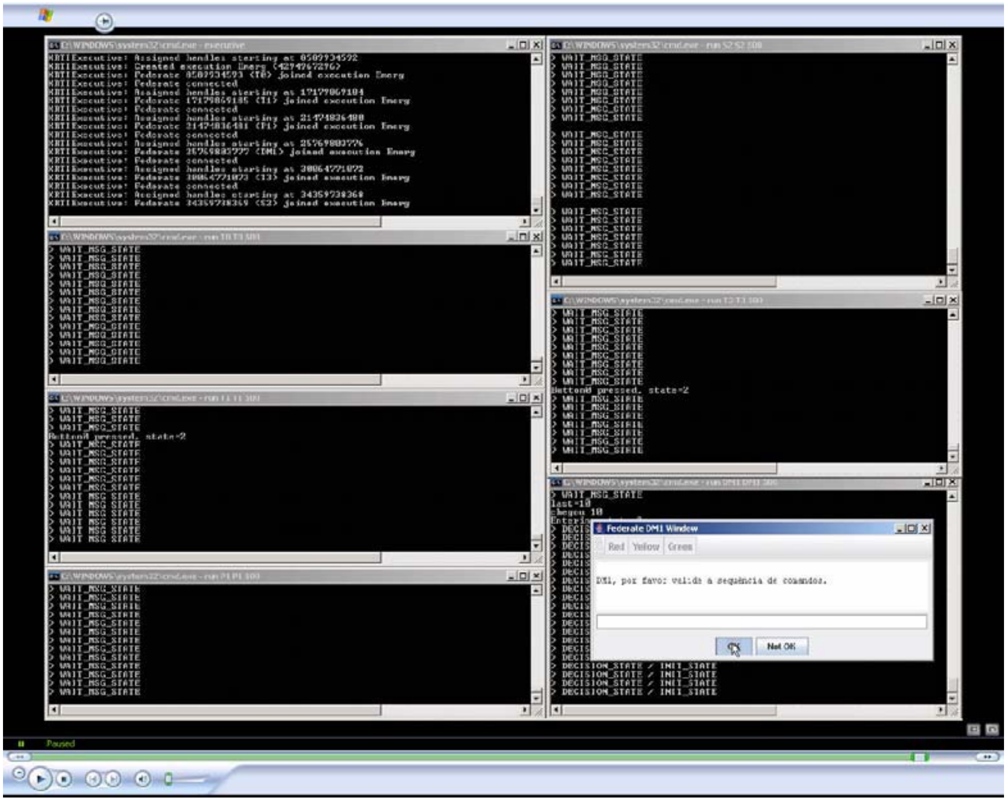

Figura 42 - O Tomador de Decisões DM1 valida a seqüência de comandos a ser executada

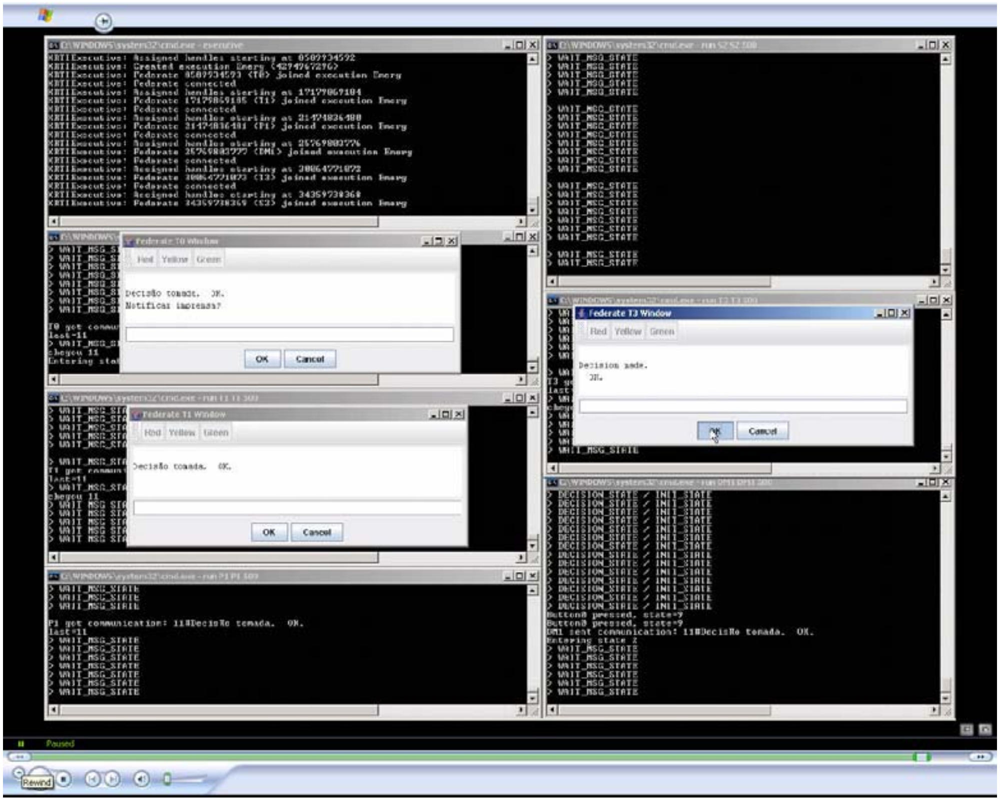

Figura 43 - Os federados T0, T1 e T3 recebem uma mensagem de DM1 informando que ele validou a seqüência de comandos a ser executada

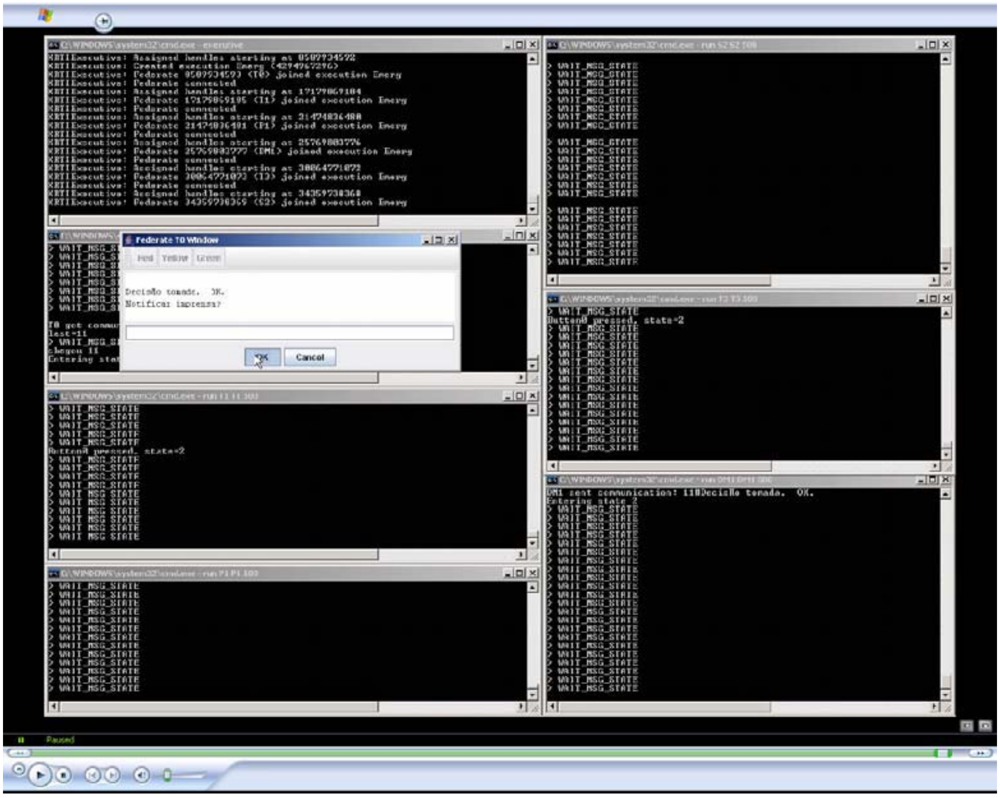

Figura 44 - O Piloto da Emergência T0 notifica a Imprensa a respeito da decisão tomada, enviando um relatório

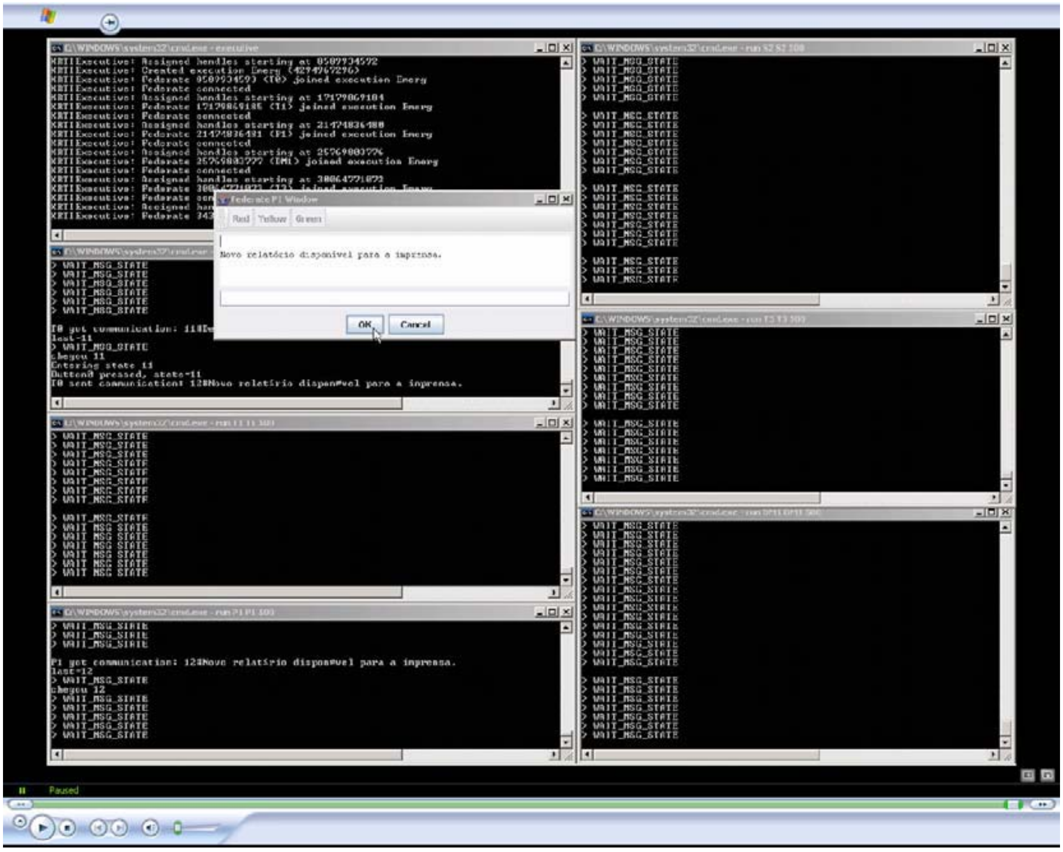

Figura 45 - A Imprensa recebe uma mensagem de T0 informando que um novo relatório está disponível