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Business Modelling for Robot Mission Control

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Contents

Abstract

This paper presents a paradigm for the organizational design of complex robotics missions.

A mission with important strategic goals and involving a large number of technological resources and different decision levels, such as complex robotics based missions, can be modelled as an organization. To avoid compromising the strategic goals, organizations modelling principles must account for the management of any crisis situations. Therefore, the mission model may have to be redesigned along the execution of the mission. This amounts to a dynamic reorganization of the mission model.

The proposed paradigm is supported on a business modelling framework to design a mission reference model, on a set of performance measures defining a set of crisis classes, and on a strategic plan that defines how the mission model is modified at a crisis situation.

The proposed paradigm is exemplified in a simplified version of the Mars Pathfinder mission, using, exclusively, public domain data.

Keywords: Business modelling, Business processes, Information Systems, Robot control architecture, Strategic plan.

1 Introduction

The technological advances in many scientific and engineering areas, e.g., materials, computation, actuators, and the decrease in economical costs are likely to increase the use of robotic devices. Several application scenarios are foreseen, e.g., multiple robots operating isolated from each other, robot teams acting in cooperation in surveillance missions, and robots working together with humans in rescue missions. In any of these scenarios, the robots are part of an organization that aims at sucessfully executing a mission.

The control architectures for robotic systems have been considered outside any organization under intelligent control architectures, [Brooks, 1986, Saridis, 1996, Albus, 1996], developed mainly for single robots, aim at providing a robot with decision autonomy. Abnormal or crisis situations may require, for instance, the reconfiguration in real time of some software components, which can only be carried out if the hardware and operating systems have the adequate design (chosen from the available off the shelf products). Therefore, the design of a complex mission may require the analysis of factors external to the robot to identify potencial problem sources. The failure in the identification of the relevant components and the relationships among them involved in a mission may thus result in the existence of the aforementioned crisis situations (see [Klein and Chrysanthos, 1999] for a definition of crisis situations). The adequate corrective actions for each identified problem source must be defined before the beginning of the mission and hence the need for a high level supervision system that has the knowledge on all the components of the whole system and, if necessary, dinamically reorganizes the whole mission (e.g., to account for environmental changes). Alternative organization design techniques can be considered. The approach in [Levchuk et al., 2002a, Levchuk et al., 2002b] differs from the proposed approach as it seeks an optimal a priori organization design, not accounting for the aforementioned crisis situations.

Mission management for robots operating in realistic scenarios amounts to a set of decision problems. These are often characterized by the uncertainty in the available information on the robot-environment interactions and hence ill-posed. The structure of ill-structured domains is difficult to capture using traditional (i.e., from software engineering) information processing models, [Reitman, 1965]. However, the study of relatively well-structured problems may give valuable insight on relatively ill-structured problems, [Simon, 1973], though decision taking skills used for well-structured problems are necessary, but not sufficient, to solve ill-structured problems, [Hong, 1998]. This paper proposes an approach to solve a class of ill-structured problems (robotic missions) using a non-traditional information processing model supported on a business modelling methodology.

Enterprise (business) management approaches to ill-structured problems are supported on a transversal view of the problems, i.e., the problem is mapped against a model of the enterprise encompassing all the business components and relationships [The Zachman Institute, 2001]. Business processes modelling methodologies usually consider the strategies, the technologies, the available resources, and the relationships among all the components in the organization, [Caetano et al., 2001].

The architecture for robot mission control proposed in this paper dynamically reorganizes the strategic goals of a mission reference model to account for crisis situations, e.g., a communications failure, a shortage in power supply, or a crash with an unexpected obstacle. The reference model is designed according the CEO business modelling principles, [Caetano et al., 2001], as it provides a framework in which the main components can be easily identified in robotics missions. Alternative modelling methodologies for dynamic reorganization, can be used in specific applications, e.g., enterprise, [Malone et al., 1999], medical diagnosis, [Filipe et al., 1999], or ocean robotics, [Turner and Turner, 1998, MIT Center for Coordination Science, 2002]. Figure 1 illustrates the three main concepts of the proposed architecture using UML, [Booch et al., 1999, Object Management Group, 2001]. The dynamic reorganization strategy maps the *perception* about the state of the system and the environment into the corrective *actions*. Each iteration of the feedback loop shown is triggered by the detection of a crisis situation.

NASA's Pathfinder mission to Mars is used as a case study, illustrating the application of the main concepts developed throughout the paper. The complexity of such a mission, involving far more than the robotics component, should be a priori clear. Public domain data, available at NASA's web site, [NASA Mars PathFinder, 2001], is used. To emphasize the parallel between the business and the robotics domains of application of the proposed methodology, the paper also discusses a simplified hypothetical business example.

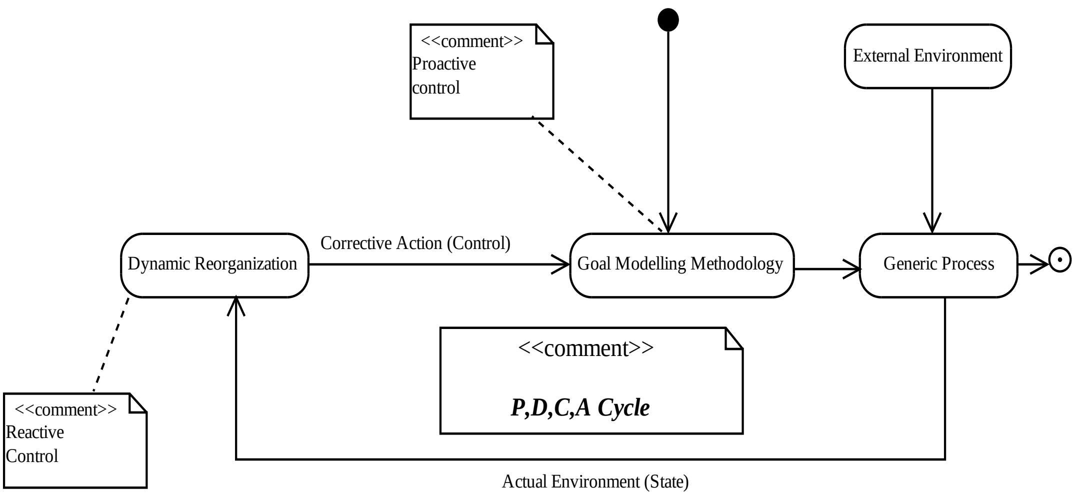

Figure 1: Business modelling loop

The proposed architecture, shown in Figure 1, is summarized by three UML states: a proactive component, represented by a, goal oriented, business process modelling methodology, a reactive component, represented by the dynamic reorganization procedure detailed along the paper, and the mission generic process to be controlled.

The paper is organized as follows. Section 2 details the main concepts of the dynamic reorganization paradigm proposed. Section 3 describes the public domain data on the Pathfinder project, goals and the components involved. Section 4 describes the initial Mars Pathfinder mission model. Section 5 demonstrates the operation of the dynamic reorganization in a crisis situation. For the sake of comparison, an hypothetical business case study is presented in parallel. Section 6 presents the conclusions and future work.

2 Dynamic reorganization and business modelling

This section summarizes the basis concepts involved in dynamic reorganization. The structure of the proposed methodology encompasses three steps:

1. identification of any crisis situations that may have occurred,

2. evaluation of the actual state of the process, and

3. decision on a corrective action based on the first two steps.

This structure is common in decision related scientific areas, being applied to problems handling information at different levels of granularity. The management of a mission involving numerous high technology systems, large human resources and complex goals requires beforehand the ability (by the management team) to understand the relationships among the main components and their role in the mission. Therefore, the information exchanged among the mission components must be structured to achieve efficiency, avoiding unnecessary details. A similar concept, the principle of increasing intelligence with precision decreasing, can be found in robotics related works, namely in [Saridis, 1996]. For instance, a corrective action may simply be defined as *change robot trajectory*, without being concerned with the kinematics of the vehicle or any other implementation details (not handled at this management level).

The corrective actions are the inputs of the mission reference model, defined using a process modelling methodology accounting for the mission goals[1] This mission reference model contains all the available knowledge on the mission and the support information system and on their relationships. The role of the goal modelling methodology is to structure the available information on the mission to simplify the assessment of how a change in a component affects the whole mission.

Given a data set on the status of a general process, the identification of crisis situations from the data set may not lead to the precise nature of the crisis (e.g., due to data insufficiency or to poor classification) and hence this is, in general, an ill-posed problem, [Hong, 1998]. Therefore, the identification must be wide sense, i.e., data is classified into crisis classes, following the principles in [Klein and Chrysanthos, 1999]. This work transcends the limitations of the "agent-local" approaches that are context-sensitive using an exception handling mechanism to identify the appropriate crisis class. A crisis class is used to diagnose a crisis situation.

[1] Alternative modelling methodologies to the CEO can be used.

The three steps of the dynamic reorganization methodology are mapped into three main components:

1. the generic process, accounting for all the available knowledge on the mission process (e.g., the type of locomotion a robot uses, the specific trajectory planner);
2. the goal modelling methodology that designs the mission reference model based on the predefined strategic goals, foreseen constraints and strategic problems;
3. a feedback controller that feeds the goal modelling methodology state with the corrective actions computed after the process data whenever an exception situation is identified and classified in an a priori defined crisis class.

These components are connected according to the diagram in Figure 2.

The core component of the feedback controller is a production system (see for instance [Russell and Norvig, 1995, Albus, 1996] for the formal definition) where the process is identified with the knowledge base. A set of rules in predicate logic (*if-then-else*) encodes the map between the crisis classes and the corrective actions. This set of rules represents the mission strategic plan. The data used by the mission strategic plan is obtained from a set of a priori defined performance measures (*process performance measures*). Each of these measures evaluates the performance of a specific activity in the mission reference model. In terms of the UML language, the dynamic reorganization state has three component states:

Process Measure Mediation, where the process performance measures are computed;

Risk Mapping, where the mission strategic plan is applied over the performance measures;

Reorganization, where the best corrective action from the set defined by the strategic plan is chosen to be sent to the goal modelling methodology state.

The goal modelling methodology defines a new mission reference model, after the corrective action proposed by the dynamic reorganization, by separating the mission strategy from the information system technologies. This separation is accomplished by defining a set of different perspectives from which to analyze the mission. In terms of a business context, three perspectives are used by the CEO approach.

Strategy, representing an integrated set of actions aiming at increasing the long term relationships and strengths between a business organization and its competitors;

Business processes, accounting for the coordination and organization of the work activities, information and knowledge, within the enterprise, to produce a product or service (see [Laudon and Laudon, 2000] for additional details);

Informational Entities, standing for the software and hardware architecture model that describes the structure, relationships and the guidelines governing the design and evolution of the building blocks that model the business.

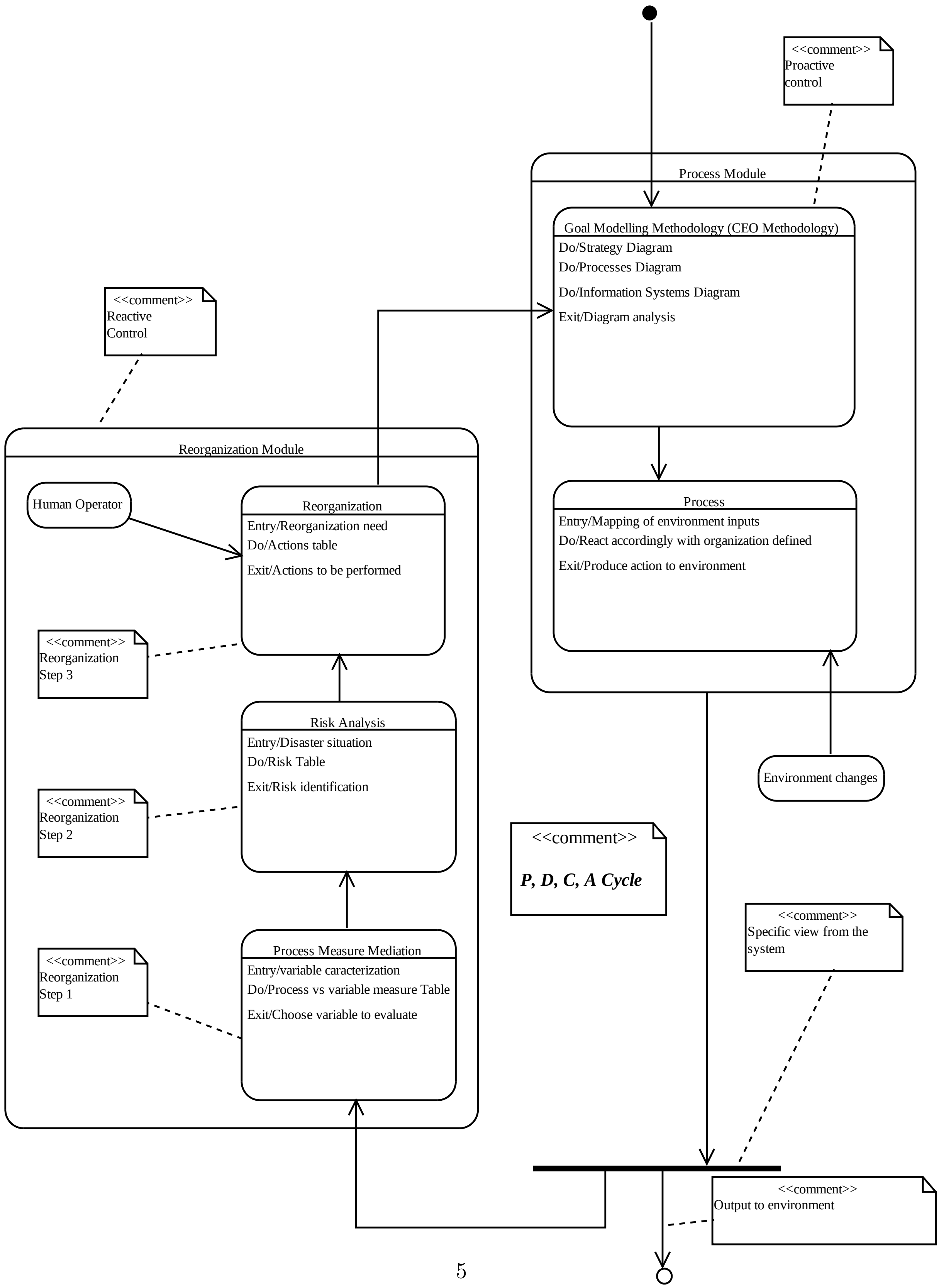

Figure 2: Expanded business modelling loop

The composition of the above three perspectives gives an overall picture of the realizations and dependencies between all the three business layers, [Caetano et al., 2001]. On a robotic mission an overall figure of this dependencies represents the traceability between mission goal and hardware/software components.

The information system technologies are analyzed according to two different perspectives.

Application components, i.e., the set of components, supporting the business processes, that are independent of the implementation technology. They guarantee that the informational entities are available at the right time and location with the adequate quality and quantity. In a robotic mission, it can be identified with the algorithms implementing a specific functionality, e.g., navigation.

Technologies, i.e., the specific technologies and infrastructures enabling the implementation of the application components. In a robotic mission it stands for the practical implementation of the algorithms involved, e.g., the programming languages and computational hardware involved.

The CEO methodology uses UML language extensions to define the stereotypes used in the different perspectives: *goal* for strategy, *process* for business processes and *extended component* for informational entities. It also defines the stereotype *contradiction* between goals when two mutually exclusive goals exist. The meta models of the extensions are presented in deep detail in [Caetano et al., 2001]. In his paper, the CEO methodology is only used to link the strategic orders to the correspondingly information entities. The issues related with the application components and technology applied to the Pathfinder mission is not the focus of this paper. This issue is broadly treated in [Pressman, 1992, Inmon, 1993, Boar, 1998].

3 The Mars Pathfinder mission data

The Mars Pathfinder mission, [NASA Mars PathFinder, 2001, Mars PathFinder, 2001], is part of NASA planetary exploration Mission. This project started in 1992 and ended by 1996, being the direct successor of the Viking project, [Viking Project Information, 2001], launched in 1975. The Mars Pathfinder was followed by the Mars Polar Lander mission (failed to reach Mars surface) and the Global Surveyor mission, the main goal being the mapping the entire Martian surface. The Mars Pathfinder mission encompassed the taking off from Earth (December 4, 1996), the space trip to Mars (7 months long), the landing on Mars surface using an airbag system (4.5 minutes long), and the exploration of an area in the neighborhood of the lander using a robot rover (until battery power has gone - around 3 months).

The analysis of the Pathfinder mission encompasses four main steps: (i) definition of the project goals, (ii) definition of the mission processes, i.e., the independent entities that support the mission, such as hardware and software modules (the counterparts of business processes in enterprise organization problems), (iii) identification of the relationships among the mission processes, and

(iv) definition of the mission deliverables. These four topics are also considered to be essential on any enterprise organization [Laudon and Laudon, 2000]. An enterprise has to design his own goals (e.g., financial or organizational goals), to define in detail his business processes (e.g., sales, buying raw materials processes), to establish an architecture for the information system that supports the entreprise activities, and to identify the deliverable expected on a time interval.

NASA defined two main kinds of strategic goals: *mission goals* and *science goals*. The main mission goals (mission expectations) identified by NASA are all related with the creation of knowledge and experience to be used on future projects.

- "Faster, better, and cheaper" project approach, aiming at reaching a three year development cycle.
- Demonstration of a low cost system able to put a scientific payload on the surface of Mars.
- Demonstration of NASA's commitment to low cost planetary exploration.
- Demonstration of the capabilities of a microrover robot on the surface of Mars.

The science goals can be summarized in a single goal that is to improve the scientific understanding of the Mars reality, [NASA Mars PathFinder, 2001]. The following set of experiments, each with its own particular scientific goal, were defined.

- Surface morphology and geology, at meter scale.
- Petrology and geochemistry of surface materials.
- Magnetic properties and soil mechanics.
- Atmospheric structure as well as diurnal and seasonal meteorological variations.
- Rotational and orbital dynamics.

Robotic technology, highly integrated with information systems technology, was used aiming at achieving the above goals (details on the technologies used can be found in the Pathfinder Web Site [NASA Mars PathFinder, 2001]).

Mission processes describe the activities (e.g., avoid obstacles), the internal functionalities (e.g., the control algorithms), the information acquisition (e.g., by the sensors), and any other a priori knowledge (e.g., environment information).

For the Mars Pathfinder mission, the following high level mission processes can be defined:

- Launching from Earth,
- Travelling to Mars,
- Landing on Mars,
- Rover driving off the lander vehicle,

- Exploring planet's surface,
- Sending information back to Earth,
- Avoiding obstacles.

The resources to be used during the mission form the set of operational functionalities. In an enterprise context, operational functionalities represent resources associated with the business process, e.g., people and raw materials.

The main operational functionalities in this mission are as follows.

Rover Robot - There are two main control schemas: (i) remote control by an earth-based operator (with an average 10 minute time delay) and (ii) local (to the rover) autonomous control, representing a sort of insect-like artificial intelligence, for instance giving the rover the ability to avoid obstacles.

Lander Platform - This is the platform where rover robot stands. It consists of four ramps the rover could use to drive off. The lander also has image capture and communication relay capabilities.

Flight System - The main task of this module is to control the mission until the landing on Mars of the lander platform.

The Pathfinder project sent back to Earth 2.6 billion bits of data, including 16.000 lander images, 550 rover images and the results of 20 different chemical analysis. After the success of this mission, NASA scheduled a number of missions to Mars, each sent during every Earth-Mars travel opportunity.

4 The Mars Pathfinder mission reference model

Given the mission data detailed in Section 3, the CEO goal modelling methodology defines a mission reference model. This model is composed by a set of three UML diagrams describing the mission components and the relationships among them. Each of these diagrams represents a different perspective from which the mission is described.

Goals diagram, defining the mission strategic options and expectations.

Processes diagram, defining the organization and integration of the mission procedures[2], information and activities.

Information systems diagram, defining the network of components that supports the implementation of the processes.

[2] A procedure is identified with a set of modules, a module being a set of components.

An empirical analysis of the goal diagram, Figure 3, results in:

- The low cost system strategic goal contradicts the fast project strategic goal. Fast prototyping requires the use of COTS (Commercial Off-The-Shelf) subsystems. However, this tends to increase the cost of the overall system. Furthermore, the effort of designing, implementing and testing each subsystem is greater than when COTS systems are used.
- The operational goals to reduce overall system cost are:
  - Use a cheap landing method (airbags instead of rocket firing);
  - Simplify the system architecture design, e.g., avoiding parallel processing computational devices;
- Demonstrating the robotic mobility in Mars harsh terrain conditions is of uttermost importance as a number of relevant scientific goals depend on the rover.
- Other contradictions may be included in the diagram, for example, the *Faster project* goal is a strategic contradiction with the *Design Robot with simple architecture* goal.

The hierarchically structured processes diagram, Figure 4, is created from the Pathfinder mission processes (see Section 3)[3].

The information systems diagram, Figure 5, identifies high level components in mission processes. Three main information system components are identified: (i) Earth based control, (ii) local control and (iii) communications infrastructures. Each component encompasses a set of smaller components (not considered in this paper).

The composition of the above three diagram results in the *GPS* diagram[4] shown in Figure 6. The GPS diagram allows the tracing of the mission goals in the supporting information system. For example, if there is some problem with the *Communications Management* component the *Sending information back to Earth* process will be in trouble and the *Science* goals might not be accomplished.

5 Dynamic reorganization in the Pathfinder mission

This section illustrates the fundamentals of the dynamic reorganization paradigm through the application to the Pathfinder mission. In parallel, a simplified hypothetical business example is introduced to emphasize the identification between enterprise and robotics concepts.

The reorganization state in Figure 2 encompasses three components:

1. A set of performance measures for each process in the mission model;

[3]This diagram is produced using the CEO methodology metamodel in UML.

[4]GPS stands for Goal, Processes and Information Systems diagram.

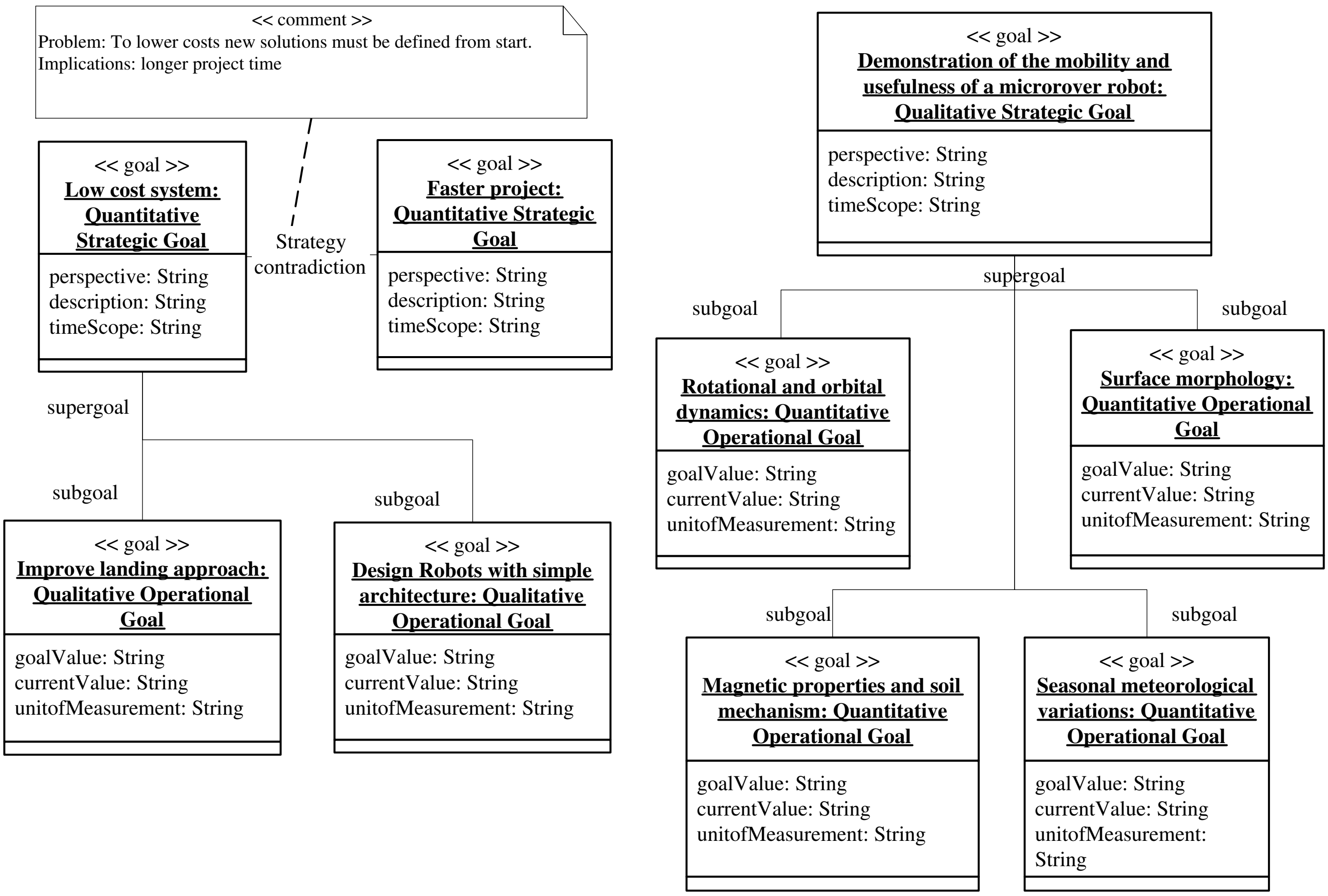

Figure 3: Initial goal diagram

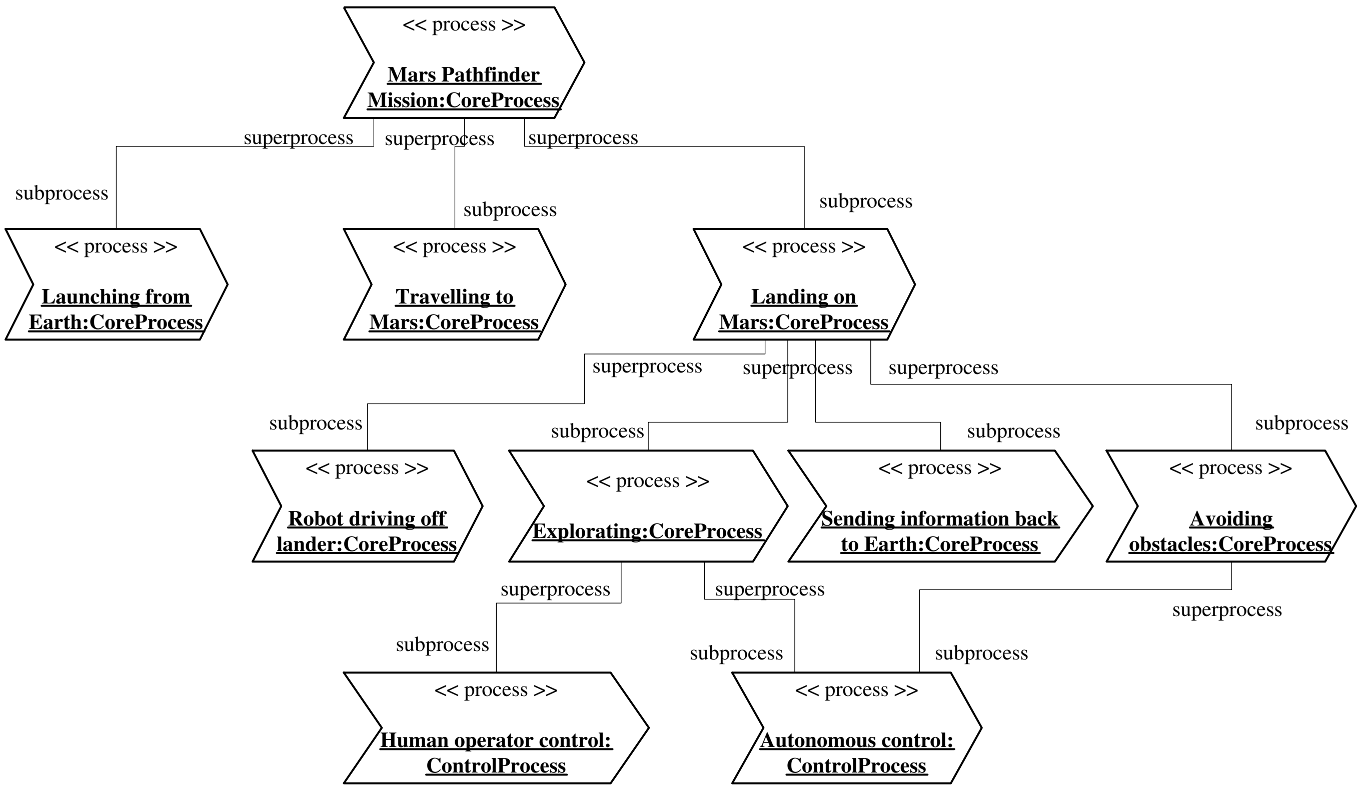

Figure 4: Initial Processes Diagram

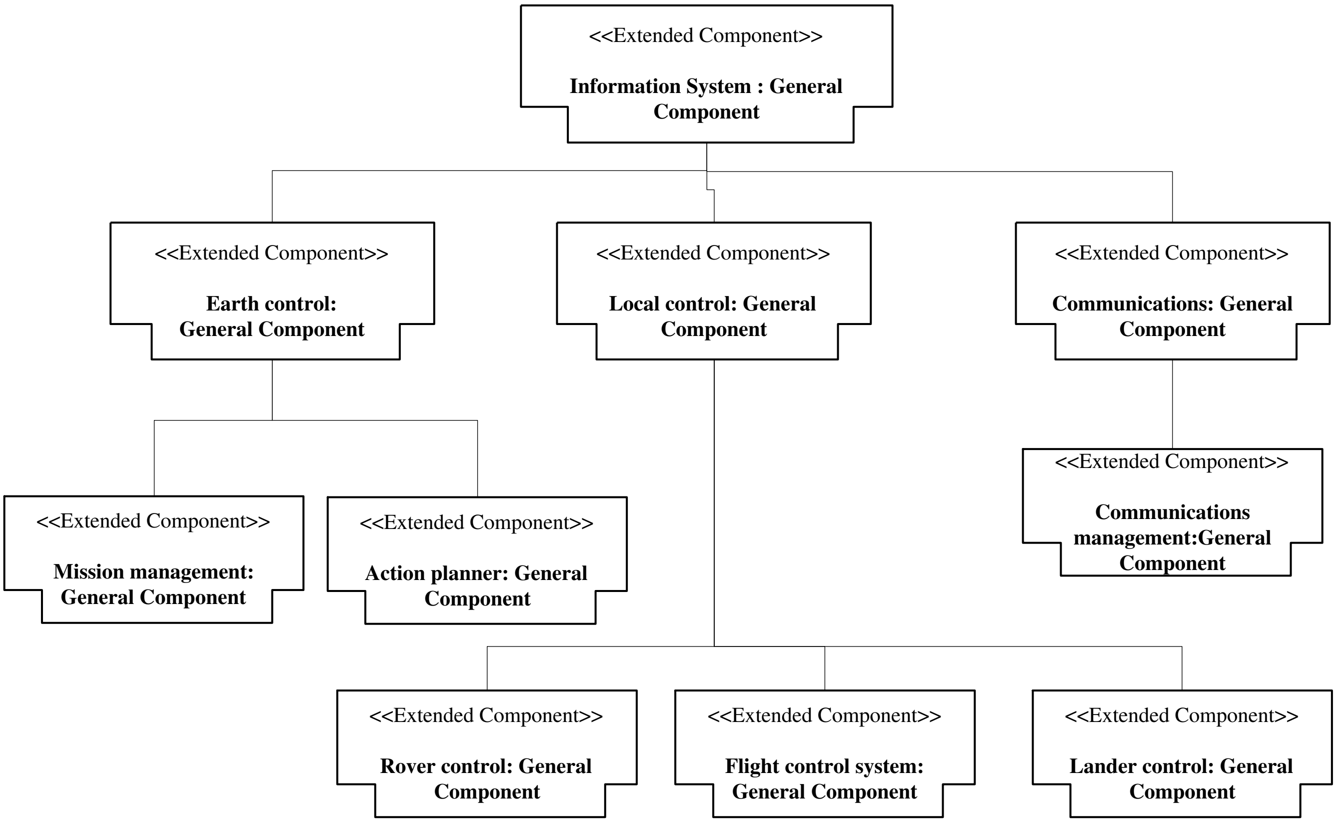

Figure 5: Initial Information systems diagram

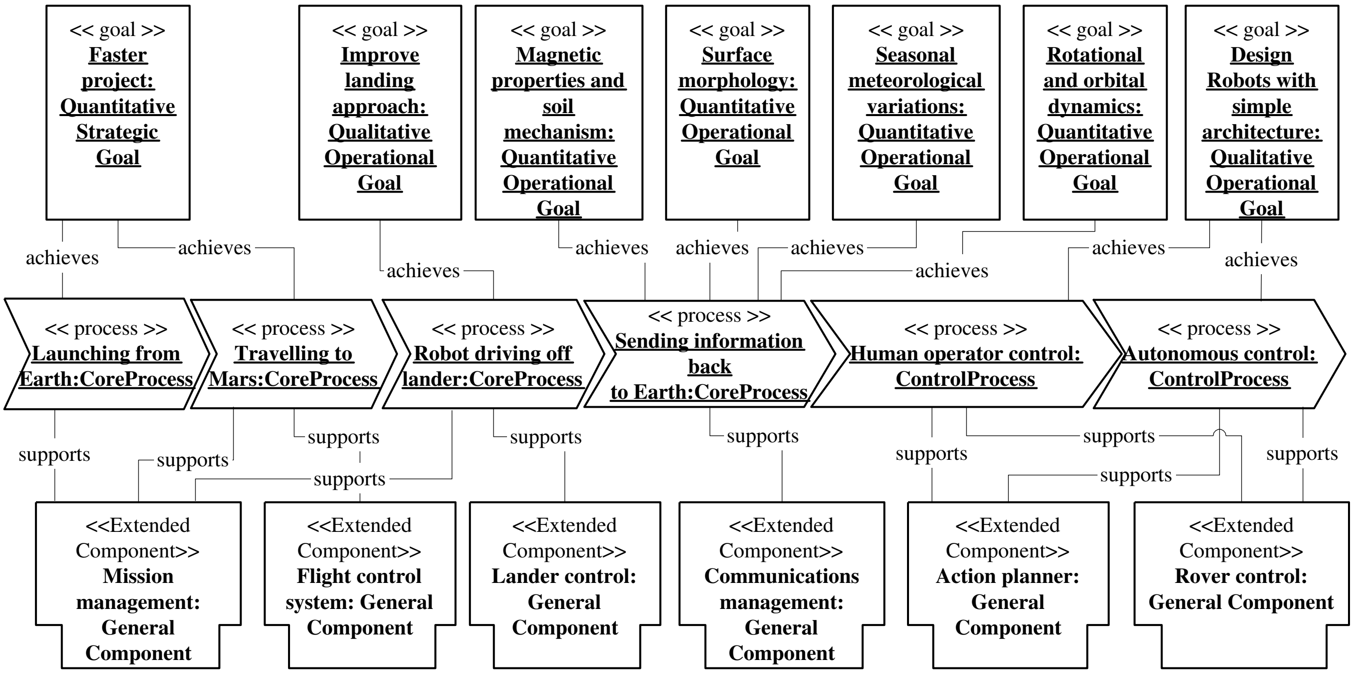

Figure 6: GPS Diagram

2. A risk analysis mapping, between the process performance measures and the a priori defined set of reorganization plans, using *if-then-else* expressions;

3. A set of corrective actions.

Whenever step 3 results in a mission reorganization and no reorganization plan matching the current status of the system is available, the system faces a *deadlock* situation[5].

Once the three steps in the reorganization state are concluded, the mission modelling state creates a new mission reference model, using the CEO methodology. This new mission model redesigns the Goal, Process and Information System (GPS) diagrams (see on section 4). This paper is not focused on the CEO methodology, and hence the redesigned GPS diagrams will not be presented.

5.1 Process performance measures - Step 1

The Process Measure Mediation (PMM) UML state in Figure 2 computes the performance measures of each mission process from the current environment status. Table 1 presents a hypo-

[5]A set of processes is in a deadlock state when every process in the set is waiting for an event that can only caused by another process in the set. In a deadlock, processes never finish execution and system resources are tied up. In practical terms a deadlock arises when a robotic system is not capable to find a solution on its own (human intervention may be needed) or when an enterprise is unable to react internally to market changes.

thetical set of measures taken from several Mars Pathfinder processes. These processes supports the Mars Pathfinder mission processes, presented on section 3. For the sake of simplicity, only the *trajectory following error* will be considered in the sequel for dynamic reorganization.

Process	**Measure**	**Goal description**
Transportation	Trajectory following error	Land safely on Mars
Local control schemas	Set of viable trajectories planned	Follow predefined paths on Martian soil
Autonomy	Operational time to battery recharging	Autonomously perform predefined tasks
Communications	Time to transmit semi-autonomous motion commands	Establish reliable communication protocol
Mechanical parts	Reliability; Lifetime; Interchangeability	Perform predefined set of actions on environment
Electronic parts	Error rates; Failure rates	Software and hardware integration
Software parts	Components reusability rate; Process control cycle timings	Process implementation

Table 1: Pathfinder processes

The reference trajectory from Earth to Mars is given to the flight navigation system along with a set of control points (see Figure 7 for a planar view) through which the trajectory must pass.

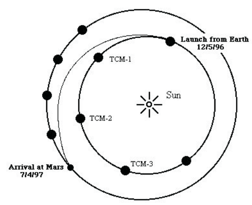

Figure 7: Pathfinder reference trajectory with the control points

Table 2 presents the enterprise counterpart of Table 1 for a generic organization, as defined by Porter's value chain analysis, [Porter, 1980, Porter, 1985]. Each row of the table only represents an enterprise process (e.g.: a specific department inside the organization) with the correspondingly measures. These enterprise processes supports the implementation of the Enterprise business processes [Laudon and Laudon, 2000].

From this set of measures, only the *number of products launched each year* will be considered. A possible reference behavior for this measure is illustrated in Figure 8.

Three control points can be identified: (i) at the beginning of year related with Valentine day, (ii) related with Summer holidays and (iii) at Christmas season. At each of these control points, the enterprise needs to release new products and services.

Process	Measure	Goal description
Finance and accountancy	Sales performance	Minimize internal expenses
Operational Systems	Core systems down-time; Time response for internal/external processes	Maintain existing systems fully operational; Propose solutions to new products/services
Human resources	Head count; Number of firm's employees with a Ph.D. degree	Achieve predefined head count
Organization and strategy	Establish a process, resource and people organization plan; Number of new launched products per year; Market shares	Improve performance on business value-chain model; Follow schedule plan to product launching; Achieve a prespecified market share
Marketing and Sales	Selling rates forecast; Propose new products or services to be developed	Gain new clients, create new value added products; Maintain actual clients, understanding their new hopes and needs; Maximize the cost-profit balance
Logistics	Stocks counting on a predefined range values	Implement just-in-time approach

Table 2: Enterprise processes

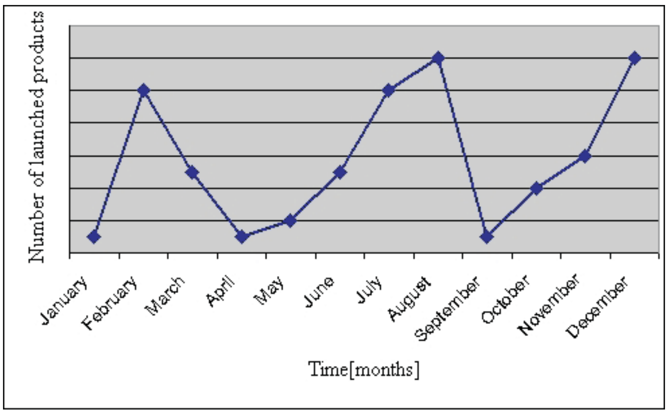

Figure 8: Products launched within a commercial year

For the sake of simplicity, only the *number of products launched each year* measure is considered to illustrate the dynamic reorganization.

5.2 Risk Analysis - Step 2

The mapping between the process performance measures and the set of strategic plans is defined through a set of *if-then-else* expressions.

For the Pathfinder mission, and the trajectory following error measure considered, NASA data indicates acceptable error values in the range ±20 km (12 miles) at each trajectory control point. Values outside this range lead either to a complete missing or even to a crash landing, without any kind of returning to NASA. This requirement leads to the following rule: *if* trajectory error > ±20 km *then* some sort of mission reorganization may be performed. Whenever this expression evaluates to true, the risk analysis state triggers the next business modelling loop state: Reorganization, see on Figure 2.

As for the enterprise case, the following expression is formulated: *if* number of products launched differs from the reference behavior *then* reorganize business.

It is worth to point that a reorganization can also be triggered directly by human intervention.

5.3 Reorganization - Step 3

Once a new corrective action is chosen by the Risk Analysis the GPS diagrams must be redesigned. This is the role of the Reorganization state in Figure 2. The new corrective actions will be expanded into more detailed reorganization actions inside the CEO methodology state.

A crisis table defines the mapping between crisis situations and corrective actions. Each corrective action sent to the CEO methodology state is mapped into a new GPS set of diagrams.

In a crisis situation, a reorganization of the Pathfinder mission amounts to a dynamic contigency plan, aiming at returning any kind of information that may help to understand what went wrong. Table 3 presents a list of a priori defined crisis classes, and the corresponding corrective actions to be taken. Each crisis class identifies a set of features common to a number of crisis situations. All the presented crisis classes are related with the *"trajectory following error"* measure identified in the Table 1. The range of values for this measure is quantified into a small number of intervals, each of which represents a crisis class.

For the sake of simplicity, only the *"damage at landing"* crisis class is considered. In practice, the exact crisis class is chosen by adding more information to the condition term of the *if-then-else* expressions defined in the risk analysis state. Due to a mistake in the trajectory calculation, the mission may not keep the initial goals. The new goals are related with image capturing and the study of dynamics of Mars. The corrective action from Table 3 is sent to CEO methodology state expressing the need to rapidly change to a contingency mode. The CEO methodology

Crisis class	Corrective action
Lost in space (bad trajectory)	Focus remaining communications capabilities on rotational and orbital dynamics of Mars and image capture of other celestial bodies.
Damaged at landing (bad landing trajectory)	Debug all systems to understand what kind of results can be returned.
Rover trajectory planning error	Send localization information to control parts located on Earth, in order to calculate new commands.
Locomotion failure (rover can not move)	Focus on goals related with image capture, air and soil analysis.

Table 3: Robotic risks versus corrective actions

is responsible to automatically reconfigure the whole mission based on the new defined goals. Figure 9 shows the new (reorganized) CEO goal diagram after the Pathfinder landing on Mars at an incorrect location.

Comparing with the initial goal diagram on Figure 3 results inthe following considerations.

- Producing a low cost mission and improving prototyping development are no longer valid goals. The Pathfinder is already on Mars and it is now time to return any possible information.
- Communications reactivation is now a main goal.
- The set of results to return remains the same.
- A strategic contradiction between establishing communications and returning results exists in the new goal diagram.

Figure 10 shows the redesigned (reorganized) processes diagram. Comparing Figures 4 and 10 leads to the following considerations.

- Launching, travelling and landing are no longer relevant processes. This process layer has disappeared since the mission is already on Martian soil.
- A new process, called debug system, includes local modules checking and trying to reestablish communications.

Finally, Figure 11 shows the redesigned information systems components. If it is not possible to locally debug, for instance due to bad communications, then debug must be performed by the Earth control component (as contingency plan). Components related with travelling and landing on Mars are no longer needed.

The execution of this methodology (from Figure 9 to Figure 11) allows the reorganization the Pathfinder mission when the crisis *"damage at landing"* occurs, in order to achieve the remaining goals of the mission.

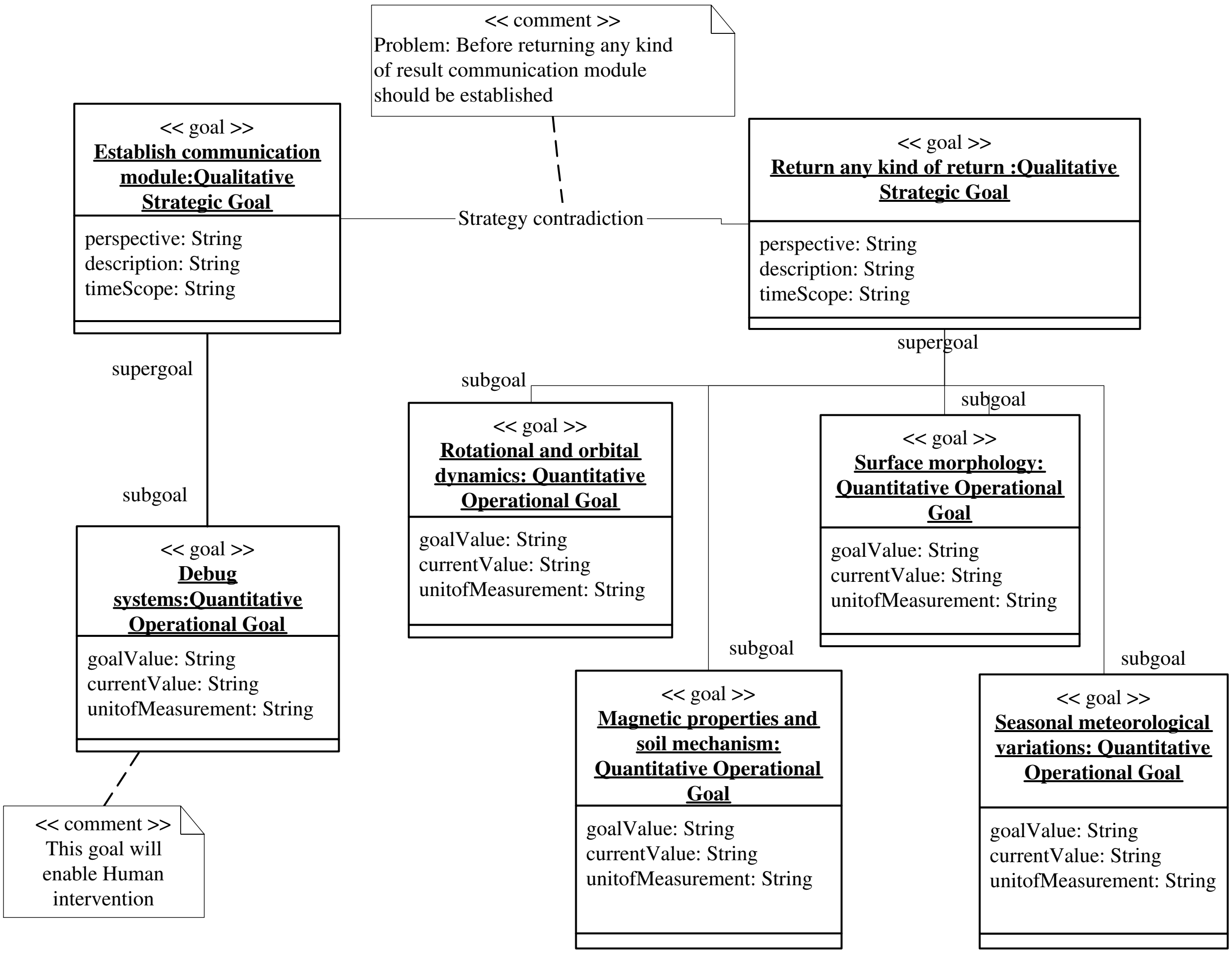

Figure 9: Robotic strategic goals reorganized

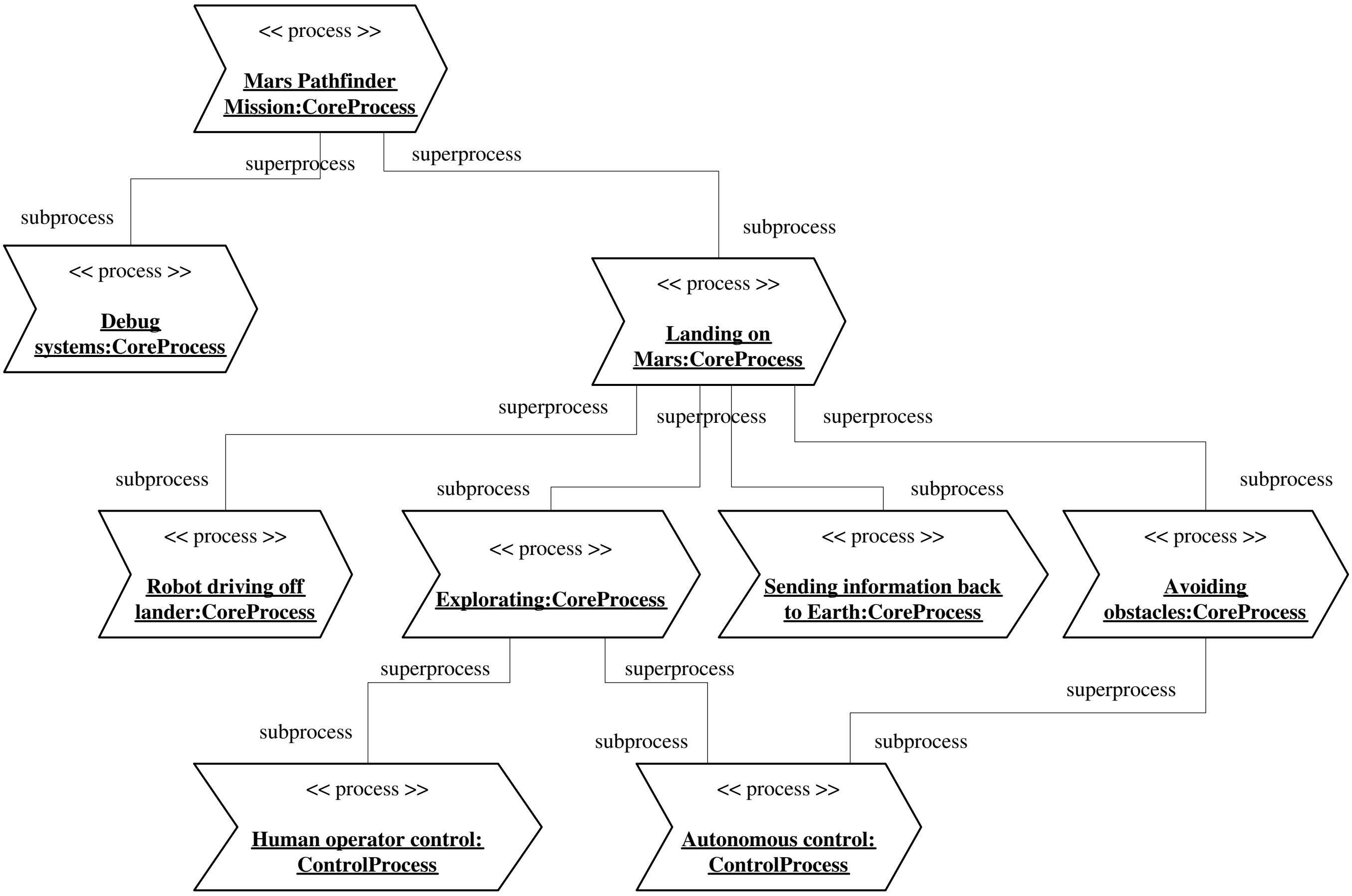

Figure 10: Pathfinder processes reorganized

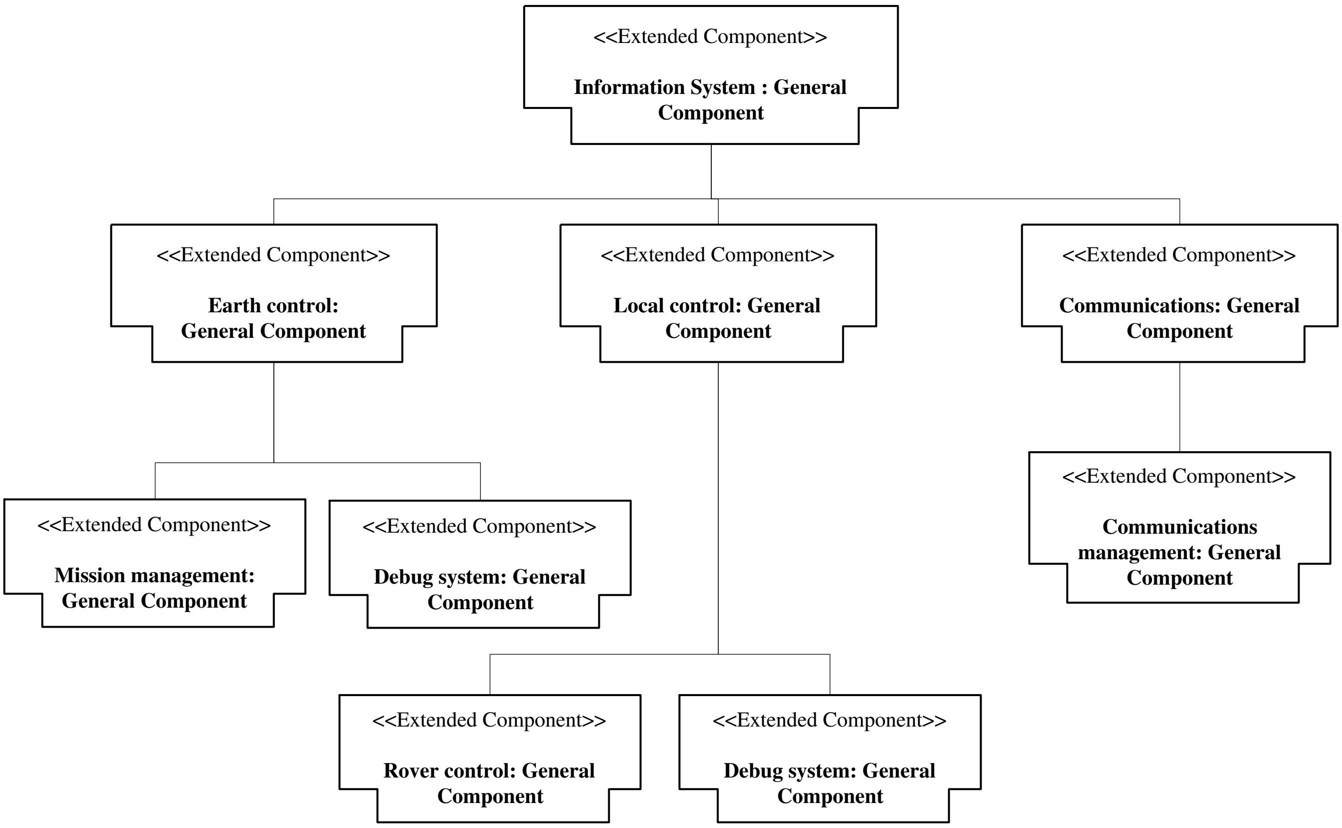

Figure 11: Pathfinder Information Systems reorganized

The crisis classes for the hypothetical business processes example are presented in Table 4. They are related with the conditional rule, defined in Risk Analysis, that uses the *new products launched per year* PPM of Table 2.

Crisis class	**Corrective action**
Lack of new product/services	Identify enterprise future directions
Products/services overlapping	Redefine enterprise product offer schedule, removing some products and including others
New launched products/services unsuitable with enterprise objectives	Identify planning errors, modify launched products
New market requirement with high priority	Redesign strategy to focus on new developments

Table 4: Enterprise business risks vs corrective actions

Similarly to the Pathfinder mission, for each crisis class defined on Table 4 a corrective action exists. If the enterprise is not able to choose a corrective action then the dynamic reorganization feedback loop faces a deadlock situation, e.g., bankruptcy or no way to react to the market changes.

6 Conclusions and future work

This paper presents an approach for the dynamic reorganization of complex robotics missions. These missions involves multiple resources, complex relationships among them and multiple decision levels falling into the organizations category. The Mars Pathfinder example presented illustrates the application of the basis concepts in business modelling to a complex robotics mission. The key point in this approach is the clear distinction among the strategic goals, the functional requirements (considered as system processes) and the technological resources supporting the implementation of the strategic goals.

The proposed dynamic reorganization paradigm is supported on (i) a reference model for the mission (or organization), obtained from a goal modelling methodology; (ii) a set of a priori defined process performance measure and corrective actions, with a strategic plan mapping one into the other; (iii) the strategic plan specifying the actions used by goal modelling methodology at each reorganization step.

Undergoing work includes: (i) the experiment of the dynamic reorganization in different context applications, e.g., enterprise organization of an industrial production system, (ii) the research on alternative technologies for the strategic plan design, and (iii) the improvement of the reference model to improve the characterization of the link between the corrective actions and the mission.

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