# Goal Modelling: Design and Manufacturing in Aeronautics

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**Abstract**

In aeronautics, the development of a new aircraft is usually organised in sequence. That means the aircraft is designed first, then its industrial system. Therefore, the industrial system may endure stringent constraints due to aircraft design choices. This can result in suboptimal performance with respect to manufacturing. But approaches such as Collaborative Engineering or Concurrent Engineering invite different engineering teams to work simultaneously and together in order to open up new prospects for a product design. In the context of a project that aims at developing methods and tools for co-designing an aircraft and its industrial system, we use Goal-Oriented Requirements Engineering (GORE) to model and to understand their respective expectations but also their dependencies. In this paper, we describe our application of goal modelling based on three iterative attempts. We start from an exploratory stage to have a global picture of the dependencies between the design of an *aircraft nose section* and its *industrial system*. We finish with a focus on a smaller problem in which we understand the key elements of the assembly line performance based on a nose design. For each attempt, we describe our results and feedback, and show how we overcame issues raised at the previous stage. We also highlight the links with known issues about GORE practical application.

**Keywords**: Collaborative Engineering, Concurrent Engineering, Goal-Oriented Requirements Engineering, Goal Modelling, Aeronautics

## 1 Introduction

In aeronautics, development is usually a sequential process. Development begins with the definition of the aircraft and the optimisation of its characteristics, and then with the definition of the industrial system and its performance optimisation. By industrial system we mean factories, production processes, supply chain, assembly lines, *etc.* This development cycle leaves very little room for optimising or fine-tuning the industrial system's own characteristics. Indeed, the industrial system is quite constrained by the aircraft design. This problem is exacerbated by a silo organisation, with one silo dedicated to aircraft design and another silo dedicated to industrial system design. Such an organisation is almost inevitable in the case of large aircraft manufacturers that have to deal with a large number of stakeholders. However, it reduces the ability to have a global vision and the potential for collaboration across silos.

It is only recently that industrial teams have been involved in the early stages of aircraft development, and aircraft and industrial system designs are seen as part of the same overall system. The idea is that the industrial system own constraints and objectives can also influence the design of the aircraft. This strong relationship between the two designs is typically what leads to Collaborative Engineering, Concurrent Engineering or even Simultaneous Engineering [13, 4]. They are well-known approaches that consist in different engineering teams working simultaneously and together in order to obtain an optimum design of several interacting systems[1]. Simultaneously designing two systems together, or what we call "co-designing" in this paper, is particularly challenging when it comes to an aircraft and its production [11]. For instance, a choice of an assembly process, such as drilling instead of welding, can impact aircraft aerodynamics. Conversely, some design considerations, such as the choice of materials, will completely define the manufacturing processes. Optimising the overall system "aircraft/industrial system" design is precisely the purpose of transformation projects in the aerospace industry, such as the *Black Diamond* in Boeing or the *DDMS (Digital Design Manufacturing & Service)* in Airbus [6]. These two companies aim to change their development practices. They want to ensure that, from the early development phases, aircraft and its industrial system are considered together.

In order to meet this challenge, we participate in a project involving academics and industrial actors to define new methods and tools for the co-design of an aircraft and its industrial system. In this respect, it was necessary to have a clear view of each system expectations and how they influence each other. To this end, we decided to apply *Goal Oriented Requirements Engineering (GORE)* approaches. GORE is a part of *Requirements Engineering (RE)* using goals, *i.e.* the objectives the considered system should meet, to express, elicit and negotiate requirements [14]. But in *RE*, the gap between research and practice is a known problem since the 2000s, and studies have been initiated to shed lights on it [3]. Méndez Fernández echoes these findings and proposes the NaPiRE (Naming the Pain in Requirements Engineering) initiative to capture RE practices and problems in industry in order to connect with the research community [9]. As an example of gap, the author points out the predominance of GORE in

[1]For additional information on the specific differences between Collaborative Engineering, Concurrent Engineering or Simultaneous Engineering, please refer to [12]

research but their shortfall in practice [8, 5]. Thus, Mavin *et al.* point out the lack of connection between research and industrial practice via a study based on a GORE literature survey and a questionnaire addressed to practitioners [7]. Some recent works have tried to bridge the gap between academic and industry domains by considering more relevant graphical layouts [15] or by investigating how agility and non-functional requirements can be handled together [17].

In a similar spirit, we try to use GORE approaches in an industrial context to identify stakeholders, to clarify both aircraft and industrial system objectives and to elicit inter-dependencies between them. In this paper, we present three iterative attempts to use GORE in collaboration with aeronautics experts. The first attempt focuses on modelling the goals of the aircraft and its industrial system with the experts using a language-free approach. The objective is to softly introduce the notion of goals to the experts and obtain a common vocabulary among their different domains. The second attempt focuses on introducing the iStar GORE language for the goal modelling. The objective is to go a step further in the usage of GORE in order to obtain a more formalised and precised goal model. An additional objective is to use a language close to the goal modelling concepts that could have emerged during the first attempt. The third attempt focuses on a narrower case study in order to push the usage of GORE even further. The objective is to learn from the two previous attempts and re-apply goal modelling from square one on some aspects of the design but in much more details. For each attempt, we present the organisation of the working sessions, the obtained model and the lessons learned from the experience. In addition, we outline the problems we face when operating the sessions.

This article is organised as follows. Section 2 describes the overall case study and its challenges. Section 3 summarises our first attempt to model aircraft and its industrial system following a GORE-like approach without using a specific language. Section 4 presents a second modelling approach for which a GORE language was introduced. Section 5 describes how we overcome some issues we had from the previous approaches by focusing on a smaller case study. Finally, Section 6 concludes the article and opens on future work.

# 2 Case Study Presentation

## 2.1 Aircraft Nose Section

Our case study focuses on an aircraft nose. We were not interested in any particular aircraft model, but in the general process of designing an aircraft nose and its associated industrial system. A schematic overview of a generic aircraft nose section is given in Figure 1.

An aircraft is built upon the assembly of cylinder sections which are equipped with all required *aircraft systems* such as electric cables, water pipes, air conditioning, waste treatment *etc.* In addition, the nose section contains the cockpit with its flight instruments (like vertical speed indicator or altimeter) and the landing gear. Because of the diversity and number of elements installed, the

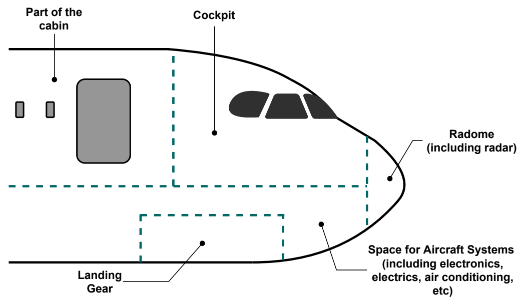


Figure 1: Generic overview of an aircraft nose section

nose section is very specific and challenging to design and to build. It faces many constraints from different fields like aerodynamics, electronics, as well as weight or ergonomics. Moreover constraints are closely interlaced. For example, ergonomic constraints related to the cockpit (*e.g.* pilots comfort or visibility) are detrimental to the aerodynamic performances. Flying requires a huge number of aircraft systems elements with their own electronics which results in several safety constraints dealing with potential failures. All these elements are heavy, require a large amount of space and must be located as close as possible to the cockpit. Design constraints must also take into account maintenance requirements, particularly between flights. For instance, it is required that faulty equipment can be replaced by functioning one during a turnaround time without interfering with ground operators, crew and passengers.

## 2.2 Manufacturing Challenges

Design choices of an aircraft have impacts on the way the aircraft is manufactured, and therefore on its industrial system. Moreover, manufacturing and assembling an aircraft nose becomes an even greater challenge when the rate of delivery increase. Thus, the way the nose section assembly is broken down into cluster of tasks is one of the key factors for efficiency. But principles design and associated technologies used to manufacture the primary structure are also essential. For instance, the use of riveting instead of welding to connect parts of the aircraft entails different consequences on industrial system characteristics like machines investment or assembly time. Other elements such as the machining of metal sheets versus cutting them into smaller ones, the number of panels to build the skin or the number of frames and stringers, lead to major differences in terms of cost, assembling time, investment, human resources, *etc.*

On top of these structure assembly challenges, there are ergonomic difficulties for the accessibility to the different areas of the aircraft under construction. For instance, operators generally have to install large and heavy elements (*e.g.* about 70 kg for element of landing gears) in small spaces with limited access (*e.g.* through a small horizontal hatch). Aside from requiring a large amount of time, the installation of these elements may occupy a large area of the aircraft under construction too (*e.g.* the stepladder to access the hatch occupies the space below it, which prevents instruments from being placed at this location). Because no assembly activities can be performed in the occupied areas, this prevents the parallelisation of activities and therefore the overall assembly efficiency.

# 3 First Application: Modelling the Overall System

In order to build the goal model to understand the dependencies between product and production, we have organised several working sessions with experts. In this section, we first describe these sessions with respect to their participants and their content. Then, we present the resulting goal model and discuss the associated feedback.

## 3.1 Goal Elicitation: Modus Operandi

**Participants**

Experts that participated in the working sessions are all members of Airbus (and its various subsidiaries). They all have many years of experience in their specific technical fields but none of them had any prior knowledge of goal-oriented approaches. Some of the experts that we call the core team, attended all the sessions and contributed to the goal model. This team was composed of two architects, specialised in aircraft design and its systems, two industrial experts, specialised in the design and organisation of an assembly line and an expert in the aircraft manufacturer's activities digitalisation. Finally, on top of these experts, there were two academic participants (authors of this paper) that are familiar with GORE approaches and served as facilitators.

**Organisation**

Six sessions took place over three months and lasted around two hours each. All sessions were organised remotely.

**Sessions content**

The first sessions objective was to have a common vocabulary among all the participants. In fact, many professions, competencies, were involved and experts had two very different cultures: the design office and manufacturing. Then, we took a few sessions to introduce the basic concepts of goal modelling approaches, along with the advantage of such approaches. It was only after all the participants had built a shared culture and vocabulary, as well as a clear vision of what a goal is, that a first goal model emerged.

In addition, two more sessions were dedicated to specific technical points. In these two sessions, some experts joined to provide explanations. Firstly, in a half-day teleconference session, two experts came to explain how they had designed an aircraft's nose. Secondly, we had a full day face-to-face session with an assembly processes expert who was able to answer technical questions that arose during the previous working sessions.

#### Goal elicitation support

Experts were free to elicit goals and their links without any formal constraints. It allowed them to confront their different cultures and to share their own vocabulary with others. The working sessions took place on a collaborative online space where each participant could create notes and link notes together. This online space has only one shape in which it is possible to write text. The only way to add semantic, i.e. to distinguish the different concepts, was the use of colours. In practice, the first sessions were dedicated to elicitation and were like *"training wheels"* stages to make the participants start reasoning about goals. We asked them to elicit their different domains goals and the relationships between them, inside their own domains but also intra-domains, in order to design the aircraft nose and its manufacturing. The last sessions were dedicated to consolidate the model by discussing the links and dependencies between the goals of the different domains and by checking the consistency of the modelling. At this point, the participants had a better understanding of goal modelling approaches and a common ground came out in terms of concepts needed for modelling.

### 3.2 Goal Model

The result of the very free notation approach was a diagram with 123 goals and 120 relationships, distributed almost equally between the design domain and the manufacturing domain. In the end, the participants informally defined and used four types of relationships: *contribution*, *decomposition*, *dependence* and *trade*. The *trade* relationship is unusual in comparison of the other relationships that can be found in other GORE languages. In our diagram, it was used to pinpoint the need for negotiation between the satisfaction of two goals. This model gave us a glance at the concepts manipulated by the participants and their capacity to express goals. An overview of the resulting diagram is shown in Figure 2. Note that there are 5 dependence relationships between the two domains. The text and some aspects have been removed for confidentiality reasons but it gives a visual insight on the size and shape of the model.

### 3.3 Discussion

#### Positive aspects

GORE approaches have been well received by the experts. They were particularly satisfied with two aspects.

First, through the GORE approach, the experts could have a global picture of the entire co-design activity. They are traditionally working in silos and it is

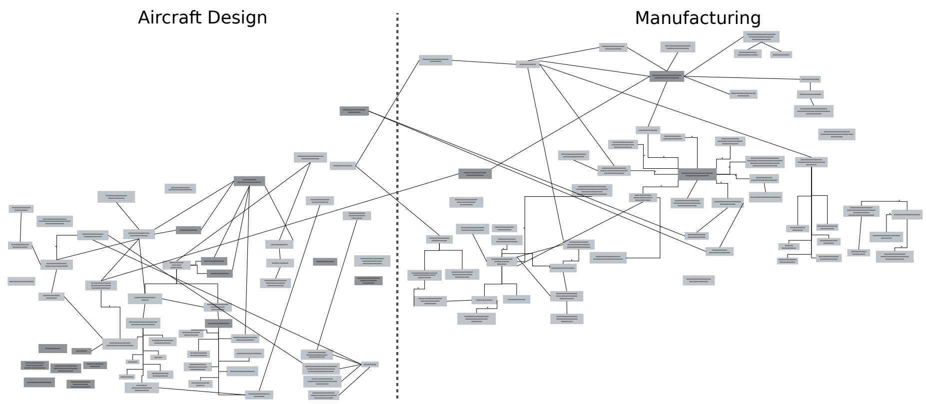


Figure 2: Overview of the goal elicitation using a online notes-based tool

sometimes not easy to think the activity globally. This view is fundamental, in order to understand the constraints and goals of each domain and to reach an optimal co-design of an aircraft and its factory.

Second, eliciting the goals allowed them to elicit the motivations of their activities. They are missing this capability. Indeed, the motivations are not present in the company processes. Even if experts know that an activity has to be fulfilled, from their experience and from the enterprise process, the reasons for it are not always obvious.

**Difficulties encountered**

We encountered various difficulties in this first attempt for applying GORE approaches. Firstly, it was difficult to understand where to start. How do you make industry experts model using GORE when they have never dealt with these concepts? So the beginning of the activity was very confusing. A step-by-step introduction, as we have done, seems to be a good way of addressing the problem in a goal-oriented way.

Secondly, the availability of experts was sometimes a problem. The more we were expanding the model, the more we realised that the core team lacked some very specific technical knowledge. Either the expert domain was not included in the core team or two experts were not present at the same time to discuss a common issue.

Thirdly, we had difficulties to obtain goals and not design solutions or tasks. It was challenging for the participants to reason at goal level. Experts were often inclined to start talking about actions and solutions rather than maintaining a rational goal level. We sometimes had to go through many sessions to be able to express a goal correctly.

Fourthly, this tendency to think in terms of actions and design solutions often led participants to debate very narrow issues, thereby losing the purpose of the activity. The sessions tended to diverge on discussions and debates about technical details and lasted much longer than planned. The sessions required a lot of moderation, it was difficult to find the right balance between letting experts debate in order to find a meaningful goal and stopping them in order to make progress on the model.

Finally, the growing complexity of the model over the sessions was difficult to manage. The activity of co-designing aircraft and its industrial system is, of course, very complex, but the model was becoming equally complex, especially in terms of relationships.

# 4 Second Application: Introducing a core language for modelling

Following this first attempt to use goal modelling approaches, we decided to take a step back and to assess the ways to proceed. We had obtained a model rich in information for our objective, but informal and with a growing complexity. The experts had also become more familiar with goal modelling. It was time to bring the activity and the experts a step further into the GORE approaches and to introduce a GORE language into the sessions. Based on the emerging types of relationships identified during the free notation approach and inspired by the work of [10], we decided to use iStar [18] to move forward with the sessions. In this section, we describe the sessions with respect to their participants and their content. Then, we present the starting point of the sessions and the resulting goal model. Finally we discuss the feedback of this next step in our application.

## 4.1 Goal Elicitation: Modus Operandi

### Participants

For these sessions, only members of the core team were present. Among them, the two architects, specialised in aircraft design were constantly present. They had some knowledge of the industrial system so they could also help clarify and translate the manufacturing side. In addition, the obtained model was discussed and reviewed with one industrial expert, specialised in the design and organisation of an assembly line, and the expert in the aircraft manufacturer's activities digitalisation. Finally, in addition to these experts, there was one academic participant from the initial two present at all the sessions. The second academic participant took part in discussions on the model between sessions and in the review sessions.

In comparison with the previous attempt, this reduction in the number of participants is due to two factors. First, it was difficult to get all the participants present at every session, their availability being limited. Second, as we already had a lot of information to work with, we were hoping that working in a smaller group of specific experts would make the moderation easier in the sessions without losing too much expertise. Having two aircraft architects with knowledge in the manufacturing was a rare opportunity to take advantage of.

### Organisation

Four sessions took place at an average rate of every two weeks during two months and lasted at most two hours each. Two of these sessions were dedicated to modelling and were organised remotely. The two other sessions were a mix of modelling and review sessions. These sessions were organised in an "hybrid" manner: some experts were present in the room, the others were connected remotely due to distance.

### Sessions content

Before starting the attempt, the free notation diagram obtained in the previous section was translated in iStar by the academic participants. During the first session, the language was introduced. Only the concepts actually used for the translation were presented and illustrated to the experts directly on the model. That includes actors, goals, soft goals, tasks, resources, refinement links, contribution links and dependency links. After this introduction, a review was done on the model: goals were reworded or removed if judged too far from our objective, tasks were created and dependencies were clarified. During the second session, the goals and tasks were refined in order to obtain a more detailed view of the aircraft nose design and the manufacturing design domain. In the last sessions, the model was reviewed and amended.

### Goal elicitation support

During all the sessions, only the academic participants had the hands on the model while the experts had a visual access to the work in progress and were able to guide the modifications. We did not have access to an online and collaborative tool to model with iStar: it was done locally on one academic participant laptop and the screen was shared in live with the experts. Between sessions, the academic participants were discussing the models and were preparing questions or modifications to suggest to the experts at the beginning of the next session. The experts also had access to a visual copy of the model at the end of each session and could review it if necessary but could not modify it.

## 4.2 Goal Model

In order to structure the free notation diagram, we translated it into iStar and introduced it to the core team. We chose iStar because the dependency relationship is one of its core elements. In fact, as highlighted in [10], identifying and characterising dependency relationships, and more specifically the dependencies between design and production, is a key point in what we call co-design. Moreover, iStar is extensible and could therefore be adapted to meet our needs. For the concepts expressed in the free notation diagram (Figure 2), the goals were first translated to goals, soft goals or tasks depending on how the academics understood them. Most of the four types of relationships which emerged during the free notation approach were translated in their counterpart in iStar. A *dependence* relationship between domains was translated as a iStar dependency link between the different actors. A *contribution* relationship was translated into a iStar contribution link. The *decomposition* relationship was translated into a iStar refinement link.

The iStar translation of the *trade* relationship was more complicated. In the free notation diagram, the *trade* relationship could be present in two cases: first to pinpoint the need for a negotiation between two solutions to achieve a goal; second, to identify the need for a negotiation about how two goals could be achieved, the way to reach one goal having an impact on the satisfaction of the other one and vice-versa. The iStar translation was realised according to each case. In the first case, goals expressing solutions to the same objective were usually combined together and translated into one iStar task expressed at a higher abstract level, where the solution is yet to decide. In this case, the need for negotiation between those solutions is encompassed in the task and the *trade* relationship is not represented anymore. In the second case, the two goals involved in the *trade* relationship were translated as soft goals or tasks in the iStar model. The *trade* relationship between them was translated in terms of heterogeneous impacts on additional soft goals, using iStar contribution links. These additional soft goals represent the reasons for negotiation.

Starting from this translation of the free notation diagram into a iStar model, the collaborative working sessions were used to iterate over the model and consolidate it. For intellectual property issues, we cannot share the resulting diagram but only describe its main features and give a visual preview of its form in Figure 3.

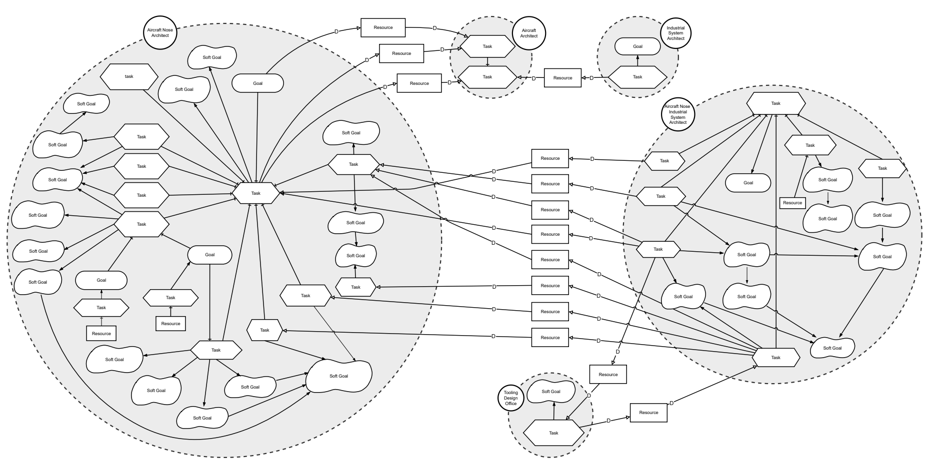

Figure 3: Overview of the goal elicitation using iStar

The resulting iStar model has 5 actors. Two actors belong to the design domain: the *Aircraft Architect* and the *Aircraft Nose Architect*. Three actors belong to the manufacturing domain: the *Industrial System Architect*, the *Aircraft Nose Industrial System Architect* and the *Tooling Design Office*. The model contains 69 elements, including 30 goals and soft goals, 24 tasks and 15 resources. There are 96 relationships: 14 of them are dependency relationships, the others are mainly refinement and contributions. Among these 14 dependency relationships, 8 are between the *Aircraft Nose Architect* and the *Aircraft Nose Industrial System Architect* (Assembly line).

## 4.3 Discussion

**Positive aspects**

The introduction of the iStar language brought some positive aspects. First, it allows a more goal-oriented modelling. There was an improvement on the expression of goals during sessions and the possibility to define tasks among goals gave a better flexibility in terms of modelling and expressivity. In addition, having a defined language and rules to model helped guide discussions about goals during the sessions. Second, the new version of the goal model brought a better understanding of aircraft design and industrial system dependencies and it was well received by the experts. The dependency description was indeed clearer and more developed than in the free notation diagram.

**Difficulties encountered**

We also faced difficulties in this second stage of GORE approaches application. First, even if we introduced a goal-oriented language which helped moderate the discussions, it was still difficult for the experts to think in terms of goals. The modelling still needed a lot of supervision to ensure we did not diverge from the initial objective. Second, despite the fact that the introduction of the iStar language brought some clarity in the modelling, the growing complexity of the model was still an issue. The goal model we obtained after the four sessions was smaller than the free-notation model and more focused on our problematic, but was still incomplete in regards to what is done in reality in terms of aircraft design and manufacturing design. The model highlighted that there was a lot of interactions between the aircraft nose and the industrial system. However, we couldn't manage to take all these dependencies into account in the model. On the other side, if we wanted to focus on a specific part of the model, the associated goals were not refined enough. So, we faced a double problem. On the one hand, we had too many dependencies between the aircraft nose and the industrial system to be able to understand them cognitively. On the other hand, we did not refine the goals enough to be able to understand how to optimise the overall system. Therefore, in order to go deeper into the technical details, we decided to reduce our system of interest.

# 5 Third Application: Narrower System of Interest

In order to reduce the complexity of the obtained models we decided to focus on a smaller system for this third attempt. In this way we hope to obtain more usable model. Focusing on a smaller system could help to reduce the number of elements while obtaining a more complete model of the system studied. Thus, instead to study the whole industrial system as we did in the previous attempts, we chose to restrict our system of interest to the aircraft nose and its *assembly line*. An assembly line is a set of stations, *i.e.* work spaces, equipped with machines and where operations to assembly an aircraft are done. In addition, compared to the global system studied above, we do not consider here the goals associated with aircraft nose designs. We only focus on understanding the key elements of assembly line performance, and this for a given aircraft nose design.

## 5.1 Goal Elicitation: Modus Operandi

**Participants**

In this application, we worked with an intermediate size team compared to the previous approaches. The team was composed of three aircraft and industrial system experts. They were all part of the previous experts team and so had prior experience with goal modelling. They had access to the model of sections 3 and 4. We did not make a selection of these experts: those who were available came. On the academic side, there were four researchers. Two of them participated in the previous goal elicitation.

**Organisation**

We organised eight working sessions over two months. The first session lasted two hours. For the other sessions, there was much more flexibility. Depending on what needed to be discussed, they lasted between 15 minutes and 2 hours. All sessions were done remotely, except the last.

**Sessions content**

The first session was dedicated to the problem presentation by the experts. They described the actors, the objectives, what they do and the dependencies in their own words. The purpose was to explain to researchers the main lines of the system to model and the differences with the overall system of interest studied previously. Based on this understanding, a first iStar model was created. Then, the other sessions were dedicated to the consolidation of this model. Between two consecutive sessions, researchers updated the iStar model with their understanding of the problem and prepared some questions on issues that needed to be clarified. On their side, experts worked on answers and completed the model accordingly. Questions were sent by email, but answers were given and discussed collectively in the session. There was no email exchange. Note that for the experts there were no iStar language constraints. So, they decided to use colour and labelled links in order to characterise the impact of tasks on goal satisfaction.

## 5.2 Goal Model

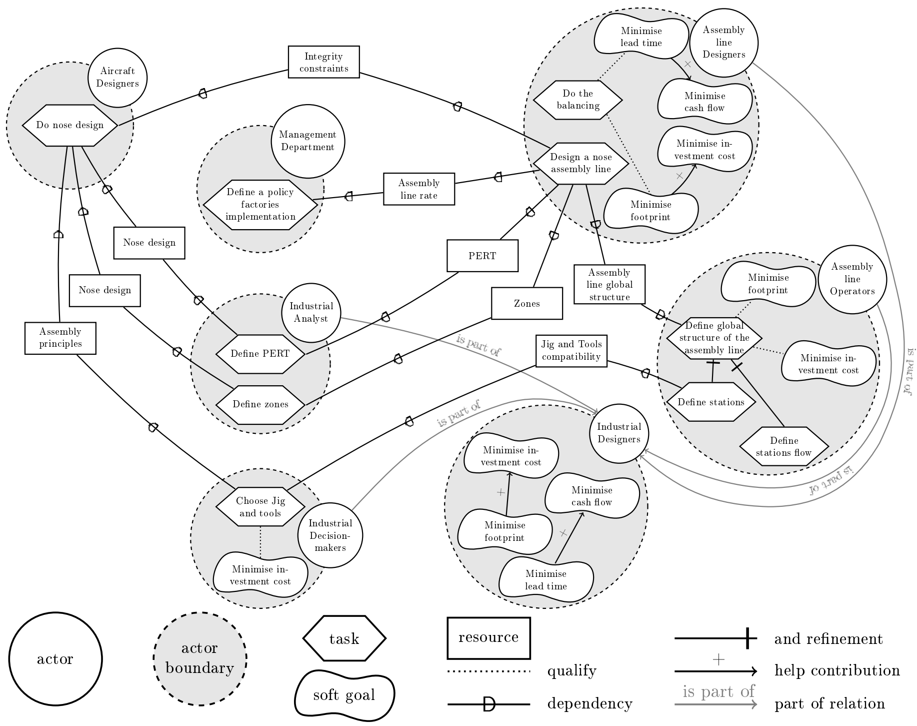


Figure 4: Aircraft nose assembly line design iStar 2.0 goal model

For this application, we used a more recent version of iStar, iStar 2.0 [2]. We obtained the model presented in Figure 4. In this model, there are seven actors. Each actor represents a company team with a specific knowledge. Note that a team can sometimes be composed of dozens of persons.

In this model, actors on the industrial system side are: *Assembly line Designers*, *Assembly line Operators*, *Industrial Analyst* and *Industrial Decision-makers*. The function of these actors is to participate in the design of the industrial system. As they share several common goals, we add a high-level actor, namely *Industrial Designers*, that contains these common goals. All industrial system actors are *part of* *Industrial Designers* actor. Therefore, they not only have their own goals to satisfy but also the *Industrial Designers* goals. On the aircraft design side, we consider a unique actor, *Aircraft Designers*, that designs aircraft. Finally, the *Management Department* actor defines targets for driving economic and strategic company policies.

Actors part of *Industrial Designers* share four soft goals, *i.e.* objectives for which there is no clear definition of when they are achieved. The soft goal *Minimise footprint* expresses the wish to minimise the floor space required by the assembly line. Contributing to its satisfaction also has a positive impact on the satisfaction of the soft goal *Minimise investment cost*. The latter represents the cost implied by the assembly line construction. The soft goal *Minimise cash flow* addresses financial aspects due to the fact that the company must buy elements to build the aircraft (*e.g.* materials or motors) before delivering the aircraft to the airline. Therefore, the soft goal *Minimise lead time*, *i.e.* the total time needed to build a whole aircraft, contributes to the cash flow optimisation.

The activities are closely linked through the *dependency* relationship. For example, the actor *Industrial Decision-makers* has the task *Choose Jig and tools* which has dependence with the task *Do nose design* through the dependum resource *Assembly principles*. This means, in order to choose jig and tools, *i.e.* what type of machines can be used by the operators of the assembly line, *Industrial Decision-makers* need to have *Assembly principles*, *i.e.* how the different parts of the aircraft are joined. The resource *Assembly principles* is provided by the fulfilment of the task *Do nose design*. In order to achieve the task *Design a nose assembly line*, actor *Assembly line Designers* needs *Integrity constraints* that describe the sets of aircraft parts that have to be assembled in the same station. This element is provided by the task *Do nose design*. The actor *Assembly line Designers* also needs to know the number of aircraft built per month. It is given by the actor *Management Department* through the resource *Assembly line rate*. Actors in the industrial system also have dependencies on each other. For instance, task *Define stations* of the *Assembly line Operators* depends on *jig and tools compatibility* given by task *Choose Jig and tools* of the *Industrial Decision-makers*.

## 5.3 Discussion

### Positive aspects

Following this work, we have discussed our results with experts. The obtained model was well received. First, as the problem was narrower, it was clearly easier to stay focused on it and elicit goals and dependencies.

Moreover, as the experts were already familiar with GORE approaches, the elicitation was much faster and there was less confusion between goals and company processes.

Finally, in comparison with the first models, the one we obtained here was at the good abstraction level for going deeper into technical details. In addition, we were able to start a discussion about the creation of an automatic tool. Indeed, following [1], it would be possible to partially automate some of the subtasks of the task *Design a nose assembly line*. In another application context, similar works have been performed for guiding software development. For instance in [16] iStar is used to study the hospital organisation in order to elicitate a platform supporting patient hospital stays functionalities. Thanks to the model, experts were able to identify which tasks could be automated and which objectives (soft goals) should be achieved by the tool.

**Difficulties encountered**

Even if the iStar framework helped us to structure the relationship between actors and elements, we faced some issues that resulted in a model that is more complex than it should. For instance, it is not possible in iStar to have dependencies between two tasks of the same actor. We needed dependencies to value the importance of some resources such as *PERT* or *Zones*. These resources are made available by the dependee task (target of the arrow) and needed by the depender task (source of the arrow). Therefore, to be able to represent these dependencies in iStar, we had to split the industrial system actor into several ones that are all linked to a parent actor in order to maintain the soft goal sharing. Another example of difficulties is the fact that a task of a given actor can only contribute to goals belonging to this actor. So we had to duplicate soft goals several times.

# 6 Conclusion

We presented applications of GORE approaches in the context of co-designing an aircraft nose section and its industrial system. Our main objective was to understand their respective key goals and dependencies between them. In this industrial context, we attempted to apply goal modelling in three different ways. In the first attempt, we obtained mixed results. Experts hadn't any experience in GORE and had only a few notions in goal modelling. They could freely use an online collaborative graphic tool to model the goals of the whole system of interest. But while GORE allowed experts to have a global picture and structure the elicitation, the resulting goal model was hard to exploit because of the size of the model and the tendency of experts to think in terms of actions rather than goals. In the second attempt, we introduce iStar syntax to a smaller group of experts. It needed a significant moderation by the academic participant to obtain a proper iStar model. But thanks to iStar syntax, this attempt allowed structuring the model and expressing goals at a more appropriate level of description. Nevertheless the model was still difficult to exploit. In the third attempt, the experts had acquired experience in goal elicitation so their supervision was reduced. They were free to use any notation on their diagram while a corresponding iStar model was build by academic researchers. This time, participants focused on a narrower system of interest. The application of GORE was quite successful as the obtained goal model allowed us to go a step further and start discussing the perimeter of an automatic tool.

From these three attempts, our feeling is that organising knowledge in terms of goals is neither easy nor instinctive for industrial practitioners. They are more likely to start by representing a system's goals with actions and design solutions. This may lead to a complex model with an inadequate level of description as we have seen during the first attempt. Using a specific goal language, as iStar, under supervision may help them to think more in terms of goals and improve the modelling. Nevertheless the size of the system of interest may also be an issue as our initial system of interest seemed too broad to obtain an intelligible model. In our specific industrial context, focusing on a smaller system eased the application of the GORE approach and the model obtained in the last attempt was more complete and usable.

For future works, we would like to address the limitations of iStar we had to face, specifically when the goal model is supposed to help the design of methods and tools for supporting decision. In such specific cases, starting from a framework like iStar, it might be possible to adapt it to use Research Operations dedicated vocabulary such as *criteria* instead of *soft goal.* Similarly, it would be possible to use different rules with respect to the dependency relationship that would allow a little more flexibility.

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