

## Application of GQM+Strategies® in the Japanese Space Industry

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**Abstract-** Aligning organizational goals and activities is of great importance for large organizations in order to improve their performance and achieve top-level business goals. Through alignment, organizational sub-units can optimize and explicitly highlight their contributions towards the achievement of top-level business goals. GQM+Strategies<sup>1</sup> provides a systematic, measurement-based approach for explicitly linking goals and contributions on different organizational levels. This paper presents results and experiences from applying the GQM+Strategies approach at the Japan Aerospace Exploration Agency.

**Keywords-component;** *Measurement-based business IT alignment; Goal-oriented measurement; GQM+Strategies; Software process improvement; Aerospace*

### I. INTRODUCTION

Aligning organizational goals and activities is of great importance for large organizations, as aligned organizations are able to achieve higher performance by improving their effectiveness and efficiency [1]. This accounts particularly for publicly funded governmental organizations like the Japan Aerospace Exploration Agency (JAXA), which have to provide a high level of accountability for their organizational goals, activities, and resource usage.

The specialized organizational units within JAXA are organized hierarchically into departments working to achieve JAXA's top-level goals. JAXA's development departments develop spacecraft in collaboration with suppliers and run space missions. JAXA's research departments contribute to JAXA's top-level goals by performing research on new technologies and transferring them into application. By focusing on alignment, the contributions of specific departments can be made transparent and associated resource usage can be improved.

The department that this paper focuses on is JAXA's Engineering Digital Innovation Center (JEDI), which is JAXA's software research department. It is tasked with improving the quality of software processes and products. This is realized via research on software techniques and technologies and subsequent introduction of these into JAXA's development departments. Sub-units (research groups) of this department focus, for example, on software

process improvement (SPI), software process assessment (SPA), and independent verification and validation (IV&V) (see Figure 1). Each department and its associated research group define their own goals, and thus it is challenging not only to refine and operationalize these goals, but also to secure their alignment with the top-level goals of JAXA.

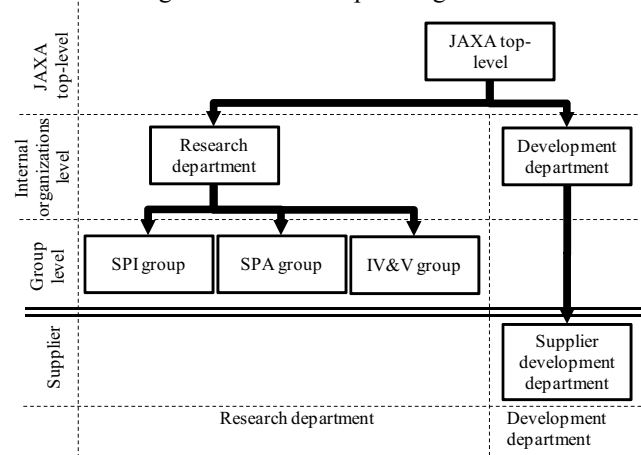


Figure 1. Target organization for aligning goals and activities

In order to address this challenge, we applied the GQM+Strategies approach at JAXA. The GQM+Strategies approach helps to clarify and harmonize goals and strategies across different levels of an organization. Furthermore, the approach facilitates monitoring the success of organizational goals and strategies [2][3]. The application of the approach did not only address the research department, but also the goals and activities of development departments and suppliers [5]. This paper focuses on the GQM+Strategies application within the software process improvement (SPI) group of JAXA's Engineering Digital Innovation Center (JEDI). There were two major goals for the application of the approach within the SPI group: (1) Clarify and align explicitly the contributions of group-level goals to top-level organizational goals. (2) Design measurement models for controlling goal achievement. Existing (lower-level) measurement models should be reused and integrated where appropriate.

This paper presents the results and experiences from this application of GQM+Strategies and is organized as follows: Section two briefly discusses related work. Section three describes the steps of the application at JAXA. Section four

<sup>1</sup> GQM+Strategies® is registered trademark No. 302008021763 at the German Patent and Trade Mark Office; international registration number IR992843.

presents an overview of the results, and section five summarizes JAXA's lessons learned and improvement suggestions for the GQM<sup>+</sup>Strategies approach.

## II. RELATED WORK

In the area of software measurement, several approaches have been developed in the last years, such as the goal-oriented GQM approach [4], which provides capabilities for guiding data selection and analysis in software projects in a systematic way. GQM provides support for measurement by developing software-related goals (e.g., for productivity or quality) and generating questions that refine those goals as well as specifying the measures that need to be taken to answer the questions. GQM and other software measurement approaches were mainly developed and are usually applied for measuring at the project level. These approaches do not focus on explicitly addressing an organization's business perspective nor the associated goals and their alignment.

Complementary to these developments in software measurement, several initiatives have also appeared in the area of corporate and IT governance. Approaches focusing on IT governance, such as CobiT [6], Val IT [7] or ITIL [8], mainly address traditional or service-oriented IT scenarios by either providing predefined sets of goals and attributes for IT infrastructure issues (i.e., CobiT) or by focusing on the description of "what should be done" and not on "how it can be done" (i.e., Val IT, ITIL). These approaches are therefore not suitable for addressing the specific alignment challenges at JAXA.

Among the measurement-based corporate governance approaches, the most prominent one is the Balanced Scorecard (BSC) [9], which provides a high-level framework for defining high-level goals and measures for different organizational perspectives (these are typically "Financial", "Customer", "Innovation and Learning", and "Internal Business Processes"). Although general multi-level implementations of BSCs exist, the approach has a major weakness in explicitly addressing technical goals (i.e., goals from the software domain) and aligning them with the overall organizational goals, as documented by Becker and Bostelman [10]. They see two major causes of misalignment: (1) project data that does not address organizational goals and (2) organizational goals that are not operationalized through processes and metrics at the project level.

The GQM<sup>+</sup>Strategies approach is an extension of the traditional GQM approach and addresses these issues by providing a method that guides the user in systematically defining goals and strategies on all relevant levels of an organization, as well as linking them explicitly. Additionally, the approach provides suitable measurement models. It is important to note that GQM<sup>+</sup>Strategies uses the notions of *goals* and *strategies* on all the levels of an organization to describe anticipated states in the future and the courses of actions needed to achieve these aspired states. Furthermore, in contrast to the BSC, the approach systematically captures context factors and assumptions about defined goals and strategies and thus enriches the GQM<sup>+</sup>Strategies model

(called GQM<sup>+</sup>Strategies grid) with information about the rationales related to each goal and strategy. This information is particularly useful for reasoning and decision making during the analysis of measurement results. The GQM<sup>+</sup>Strategies grid integrates all the elements described above. Therefore, the approach does not only help to harmonize goals, strategies, and measurement, by providing traceable connections between associated goals, strategies, and measurement models, but also provides a measurement system for the effective control of goal achievement and the success of strategies [2]. Figure 2 gives an overview of the basic GQM<sup>+</sup>Strategies concept.

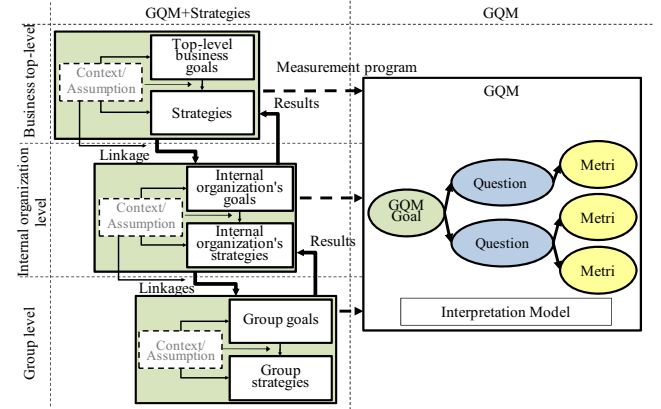


Figure 2. Basic concept of GQM<sup>+</sup>Strategies

## III. GQM<sup>+</sup>STRATEGIES APPLICATION AT JAXA

The GQM<sup>+</sup>Strategies application at JAXA was performed together with measurement experts from the Fraunhofer Institute for Experimental Software Engineering (IESE). Modeling a GQM<sup>+</sup>Strategies grid can be either performed top-down or bottom-up. It usually makes sense to obtain some initial knowledge about top-level goals and strategies; therefore, we used JAXA's "2025 Vision" [11] documentation as a starting point. The application of the GQM<sup>+</sup>Strategies approach at JAXA was performed using the following steps (see also Figure 3):

1. Enhancing the understanding of the GQM<sup>+</sup>Strategies approach
2. Defining the scope of the GQM<sup>+</sup>Strategies application
3. Gathering the existing assets
4. Defining the top-level business goals
5. Defining the strategies
6. Iteratively defining the goals and strategies until coverage of the scope is achieved
7. Defining the GQM measurement models (or mapping the existing GQM models)
8. Visualizing the GQM<sup>+</sup>Strategies grid and the GQM measurement models

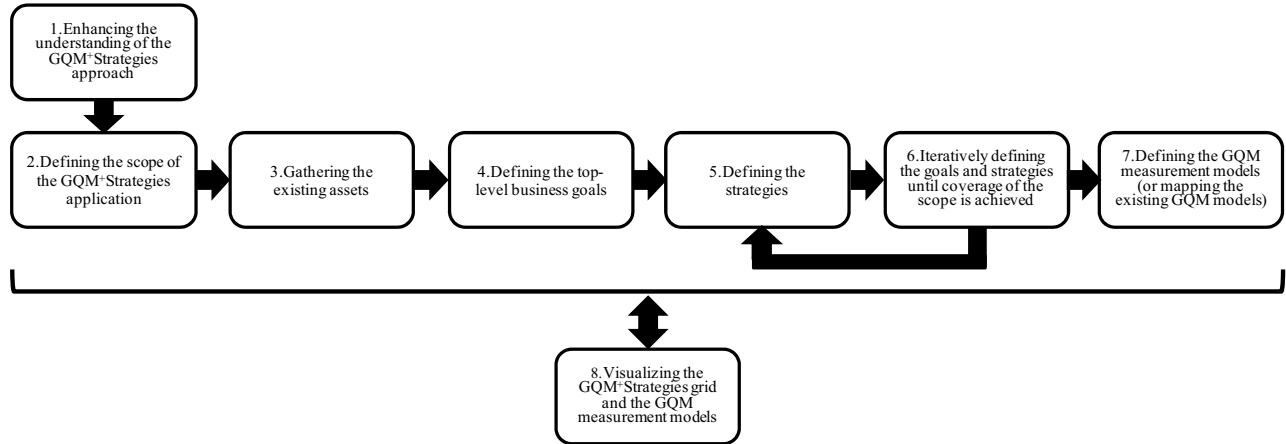


Figure 3. Steps of GQM<sup>+</sup>Strategies application at JAXA

#### A. Enhancing the understanding of the GQM<sup>+</sup>Strategies approach

In order to create an understanding of the concepts and benefits of aligning goals and activities, training was performed in the form of a guided tutorial on the GQM<sup>+</sup>Strategies approach. It was essential for the engineers who later on applied the GQM<sup>+</sup>Strategies approach. Managers from the software research department also participated in the tutorial session as they are responsible for the goals and strategies of their group. Management commitment and their participation in the tutorial session motivated the engineers to apply GQM<sup>+</sup>Strategies for their group and thus was an essential facilitator.

#### B. Defining the scope of the GQM<sup>+</sup>Strategies application

In order to define the scope of GQM<sup>+</sup>Strategies, it is important to consider the main purpose of the respective organization. Covering every activity of the organization was not feasible because of time and budget limitations. Thus, the focus was placed on the most important organizational units and activities.

JAXA's mission is to explore space. For this purpose it is essential to develop high-quality spacecraft that are capable of contributing to the space exploration mission. In this context, the supporting research departments play an important role. They do not only perform research on new technologies and transfer these into application in the development departments, but they are also dedicated to continuously improving the quality of JAXA's products and services. Thus, the scope of JAXA's GQM<sup>+</sup>Strategies application was not only limited to JAXA's development departments, but particularly included JAXA's software research department as well as JAXA's Engineering Digital Innovation Center (JEDI) and its sub-groups. The work at JEDI specifically focuses on researching and improving technologies for JAXA's software development departments. As JAXA collaborates with suppliers in spacecraft development, these were also included in the application scope. However they will not be discussed in detail in this paper.

#### C. Gathering the existing assets

The benefit of gathering existing assets is the potential of possibly reusing some of those assets. Typical assets are goals, strategies, and GQM models. Additionally, analyzing existing assets also helps to identify missing assets and thus existing gaps. JAXA's software development standard was identified as an asset because measurement activities are defined in it. Furthermore, JAXA's documented "2025 Vision" [11] was used as another asset. By gathering and reusing existing measurement assets, it was possible to reduce the effort during the application of GQM<sup>+</sup>Strategies.

#### D. Defining the top-level business goals

In order to clarify the contribution of the activities of internal organizations to top-level business goals, it was necessary to include the top-level business goals. Often these goals are either success goals (e.g., deliver high-quality products to customer, increase profits, etc.), growth goals (expand existing projects set, evolve existing market, etc.), or maintenance goals (maintain employee satisfaction, keep risk level controlled, etc.).

JAXA's top-level business goals are officially published in JAXA's "2025 Vision" [11]. Based on the "2025 Vision", the focus was put on goals covering "improve contribution to space exploration", "improve user satisfaction", and "improve tax payer satisfaction".

#### E. Defining the strategies

In order to achieve the top-level business goals, suitable strategies need to be defined. JAXA's top-level strategies are also officially published. A set of the published strategies was selected. Additionally, some strategies were developed for achieving top-level business goals using brain-storming. The brain-storming sessions turned out to be an effective way to develop a variety of ideas for suitable strategies.

#### F. Iteratively defining the goals and strategies until coverage of the scope is achieved

In order to achieve alignment from top-level business goals to internal organizational goals and activities, it is necessary to identify potential lower-level organizational

goals that help to achieve the chosen higher-level organizational strategies. Subsequently, lower-level organizational strategies are defined to achieve the goals of lower-level units. The iterative definition of lower-level goals and strategies is performed until the defined scope is covered.

The organizations that were in the scope of JAXA's application were the JAXA development department, the software research departments, and the suppliers. The iterations performed with the members of JEDI focused on the SPI group; for them, the approach was applied iteratively starting from JAXA's top-level business goals to JEDI's activities and furthermore to the project level within the SPI group.

#### G. Defining the GQM measurement models (or mapping the existing GQM models)

Defining the GQM models for each selected GQM<sup>+</sup>Strategies goals is important for analyzing and evaluating goals and strategies. If there are already GQM models that were identified during the "gathering assets" steps, it may be possible to reuse the existing GQM models, which reduces modeling effort. In the case of the application at JAXA, several existing measurement models could be reused by mapping them to respective goals within the GQM<sup>+</sup>Strategies grid. But new measurement models were also developed, particularly for the goals related to the SPI group.

#### H. Visualizing the GQM<sup>+</sup>Strategies grid and the GQM measurement models

Visualizing the alignment of top-level business goals with the relevant department- and group-level goals in the

grid enhanced understanding, communication, and discussion while applying GQM<sup>+</sup>Strategies.

Visualizing the GQM<sup>+</sup>Strategies grid was not only performed at the end of GQM<sup>+</sup>Strategies application, but also during each step of the application. Visualizations of intermediate modeling results of the grid were used during each iteration for communication, discussion, and continuous evolution of the model.

### IV. RESULT OF THE GQM<sup>+</sup>STRATEGIES APPLICATION

The objectives of the GQM<sup>+</sup>Strategies application in the context of JAXA were defined as follows:

- (1) Clarify and align explicitly the contributions of group-level goals to top-level organizational goals.
- (2) Design an associated measurement system, reusing (lower-level) existing measurement models where appropriate.

In order to achieve the first objective, aligning top-level business goals and strategies with goals from the relevant organizations, as defined in the application scope, was necessary. The lower-level goals and activities at the department and group levels were defined based on higher-level organizational goals. Therefore, the resulting GQM<sup>+</sup>Strategies grid structure is similar to JAXA's organizational hierarchy.

In order to achieve the second objective, GQM models were mapped or defined and linked to corresponding GQM<sup>+</sup>Strategies goals. In summary, JAXA's top-level business goals and JAXA's goals from lower levels of the organization were defined and linked creating the GQM<sup>+</sup>Strategies grid. Then measurement models were associated with the defined goals in order to make them controllable.

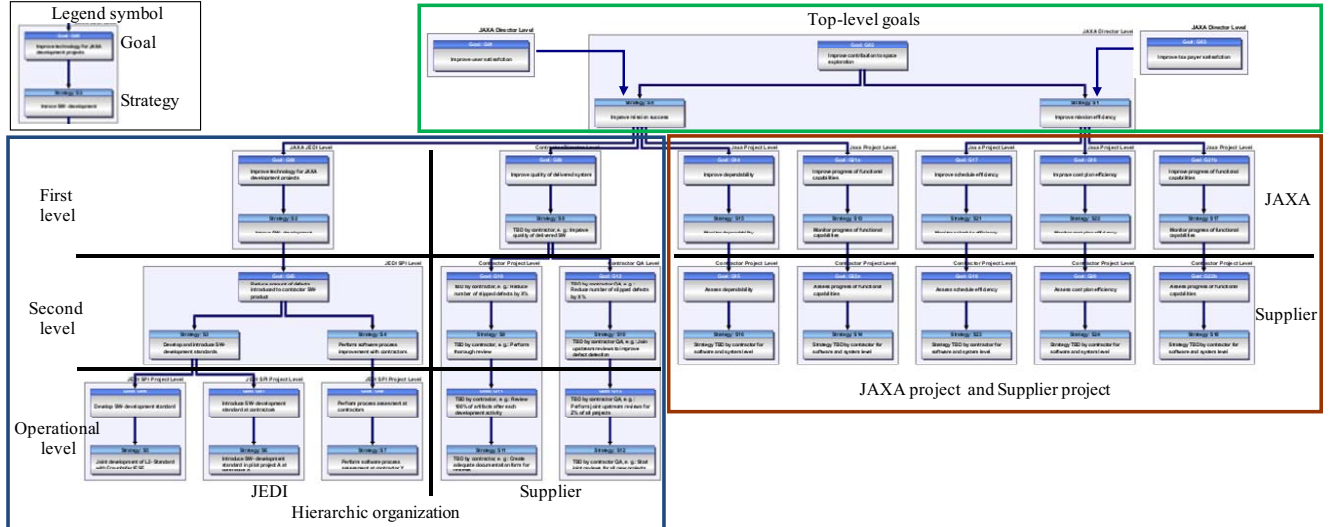


Figure 4. GQM<sup>+</sup>Strategies grid

#### A. GQM<sup>+</sup>Strategies grid

Figure 4 shows the resulting GQM<sup>+</sup>Strategies grid. In this grid, top-level business goals and strategies were refined to projects, JEDI, and suppliers. The following top-level

business goals were selected based on the officially published vision:

- (G1) Improve contribution to space exploration
- (G2) Improve user satisfaction
- (G3) Improve tax payer satisfaction

The first top-level business goal (G1) is a reasonable goal for a space agency. It defines JAXA's existence and is therefore of great significance. The first top-level business goal is refined into the following top-level strategies:

- (S1) Improve mission success
- (S2) Improve mission achievement efficiency

The first strategy (S1) is obvious for the space exploration goal. However, resources (e.g., budget, human resources, physical constraints) need to be considered. Hence, the contribution of lower-level activities is assessed using these two perspectives.

The second top-level business goal (G2) "User satisfaction" was linked to the first strategy "mission success". Mission success is achieved when JAXA is able to provide enough service and data to the respective users. A user is a person who uses JAXA's systems and services.

The third top-level business goal (G3) "Tax payer satisfaction" was linked to the second strategy (S2) "Mission achievement efficiency". The main reason for this is the fact that JAXA is a publicly funded organization and therefore resource efficiency is required in order to achieve efficient usage of tax payer money for space explanation.

The left side of Figure 4 shows the linkage of top-level business goals, JEDI goals, and supplier goals. It provides JEDI's and the suppliers' contribution to the top-level business goals. The detailed linkage of top-level business goals, JEDI goals, and strategies is described in a later section.

The right side of Figure 4 shows the alignment of top-level business goals, JAXA project goals, and supplier project goals.

#### B. GQM<sup>+</sup> Strategies grid details from the SPI Group perspective

The top-level business goal and strategy "Improve mission success" was refined into four unique lower-level goals. The goal that is most relevant for JEDI is the goal "Improve technology for JAXA development" (see Figure 5). Dissemination of new effective technologies is important for JAXA and mission success and, in consequence, the top-level business goals "User-satisfaction" and "Contribution to space exploration" are supported directly. At the JAXA research department level (JEDI level), the dissemination and effectiveness of technological improvement is monitored based on aggregated measures, which are composed from the results of the different JEDI research groups. Thus, JEDI shows its overall contribution to top-level business goals. In order to achieve the JEDI goals, a software-specific strategy "Improve software development" was defined.

This strategy was then further refined to the group level. In our case, we focused on the SPI group and its goals and strategies. At the SPI group level, the goal "Defect reduction" was refined based on the department-level strategy "Improve software development" (JEDI-level strategy). Then this goal was refined into two strategies. The actual technological improvement performed and the dissemination as well as the effectiveness of the results are measured. Aggregation provides transparency of the contribution of each group without imposing supervision of

every group activity. At the same time, the measured data provides valuable information to group leaders about the success of technology improvement activities.

Based on these strategies, the GQM<sup>+</sup> Strategies grid was further refined on the operational SPI group level. Software process assessment is performed as one of this group's operational activities to achieve the SPI group-level goal "Reduce number of defects introduced to contractor software product". This operational activity was aligned with the SPI group-level strategy within the grid. Additionally, an explicit alignment from the top-level business goals to the operational-level goals was achieved, as a consistent and traceable link within the grid was refined.

In order to evaluate the achievement of the goals, GQM models need to be defined or predefined GQM models need to be mapped to respective goals in the GQM<sup>+</sup> Strategies grid. Such a mapping allows for reusing GQM models. Thus, measurement models are not only used to evaluate the achievement of the mapped goals, but also to evaluate the contribution to top-level business goals. Figure 6 shows one of the defined GQM models, which allows evaluating the achievement of the SPI group's operational-level goal. The measurement goal is to evaluate the performance of process assessment activities at contractors. To evaluate the performance of process assessment, a question that deals with the "Degree of JAXA SW process assessment dissemination" was defined. In order to answer this question, "Number of assessed contractors / number of all contractors" was defined as a metric.

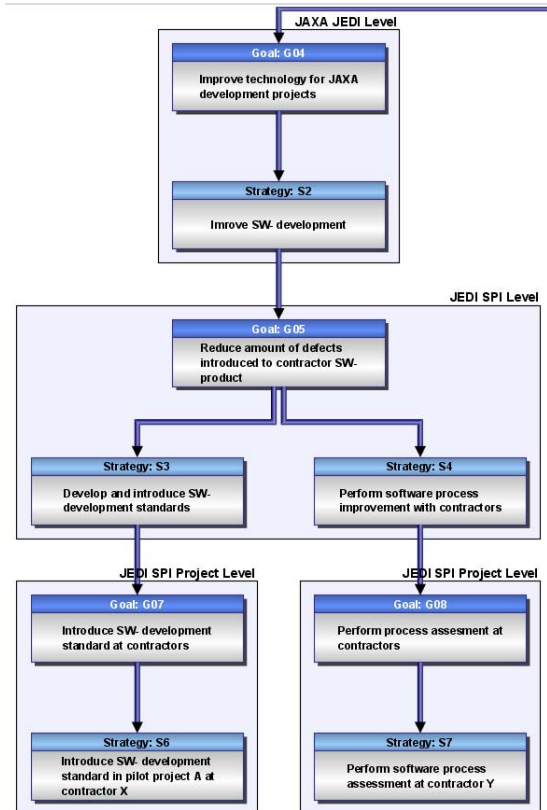


Figure 5. Group-level and operational-level GQM<sup>+</sup> Strategies grid



GQM Goal	Object	Purpose	Quality Focus	Viewpoint	Context
Process assessment	Process assessment	Characterize	Dissemination	JAXA JEDI SPI	JEDI SPI Project
Questions					
■ Q1: What is degree of dissemination of JAXA SW-process assessment?					
■ Q1.1: What is the number of JAXA contractors where process assessment is performed?					
■ Q1.2: What is the total number of JAXA contractors where process assessment could/should be applied?					
Metrics					
Dissemination		(#assessment performed) / (#all contractors)			Q1
#assessment performed		Number of contractors where assessment is performed			Q1.1
#all contractors		number of JAXA contractors where assessment could / should be performed			Q1.2
Decision criteria					
Dissemination ≥ X (threshold e.g. 90%)					

Figure 6. GQM model

## V. DISCUSSION AND CONCLUSIONS

For the specific application of the GQM<sup>+</sup>Strategies approach at JAXA described in this paper, two main goals were defined. The first goal aimed at clarifying and explicitly aligning the contributions of group-level goals to top-level business goals. The second goal aimed at designing measurement models for controlling goal achievement. Existing (lower-level) measurement models should be reused and integrated where appropriate.

Applying the GQM<sup>+</sup>Strategies approach delivered a measurement program that included multiple organizations (i.e., development departments, research departments, and suppliers). For some goals, it was also possible to reuse measurement models that already existed at JAXA. Thus, we were able to achieve the second goal.

Furthermore, following the described steps during the modeling of the GQM<sup>+</sup>Strategies grid, we were able to link different activities of the SPI group to JAXA's top-level business goals and its overall vision. Thus we could clarify how the goals of lower-level groups contribute towards top-level business goals. Consequently, we were also able to achieve the first goal by applying the GQM<sup>+</sup>Strategies approach. In addition, the GQM<sup>+</sup>Strategies grid made the relationship between top-level business goals and measurement programs transparent, including those of suppliers. This experience of using the GQM<sup>+</sup>Strategies approach at JAXA shows that the approach helps to clarify the relationship between activities of different organizational units on different levels of the organization, as well as to explicitly show the contributions of those activities to the achievement of top-level business goals.

From this application of GQM<sup>+</sup>Strategies the lessons learned were derived: Involvement of personnel from the involved organizational units is essential for discussing, modeling, and verifying the models. This is particularly true for making sure that lower-level organizations goals fit to higher-level organizational strategies and vice versa.

In order to reduce the development effort of the GQM<sup>+</sup>Strategies grid, it is important to reuse previously developed GQM<sup>+</sup>Strategies components as well as GQM measurement models. Therefore, it is also beneficial to analyze the developed GQM<sup>+</sup>Strategies grid in order to identify patterns that could be reused in the future.

Additionally the following, GQM<sup>+</sup>Strategies improvement potentials were identified: At this stage of

development, the GQM<sup>+</sup>Strategies grid visualizations do not show the current status of goal achievement by means of an analysis of the collected data. This feature is needed in order to enhance understanding and discussion and to improve and refine existing strategies.

Currently, the GQM<sup>+</sup>Strategies grid does not address the priorities of different goals and strategies. Priorities could be set by considering the importance and contribution to higher-level organizational goals, as well as passing those down to lower-level goals. In the event of changes in resource availability or in the business environment, organizations need to adapt their goals and strategies, including lower-level goals and strategies. Providing the contribution and priority of those goals and strategies will enhance the process of decision making.

At this moment, there is no support for systematically evaluating and quantifying the effects that the application of the approach has. Currently it is only possible to make qualitative statements about perceived benefits or to analyze the collected measurement data with respect to goal achievement. An evaluation framework is currently under development, and a systematic evaluation of the application at JAXA is planned. Nevertheless, it can be concluded from JAXA's perspective that GQM<sup>+</sup>Strategies supported the alignment and measurement of goals from different organizational units, within JAXA's organizational hierarchy.

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