INTEGRATION OF A SCENARIO METHOD IN AIRBUS' TECHNOLOGY AND PROJECT EVALUATION

Matthias Meussen*, Axel Becker**
***AIRBUS, **DaimlerChrysler**

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Abstract

For a technology evaluation that is based on technical and economic models, quantified, numerical (input) parameters are prerequisite. As these parameters are projections of a (far) future they are by nature difficult to obtain and subject to discussion. To deal with the wide variety of future developments, methods have been used to analyze the environment and to create consistent scenarios.

The paper describes the implementation of a modified scenario process in the technology and future projects assessment method at AIRBUS. It describes in brief the approach of technology evaluation and risk analysis that is based on technical and economic models. The intentions of scenario use and the baseline scenario method are outlined. The modifications to the method are discussed and the implications are shown, including an example application.

1 Introduction

The development of new technologies requires long-term investments in terms of time, resources and money. To secure these investments and to guide the development of technologies towards a successful implementation into future products, AIRBUS has established a process to support technology evaluation. This process requires information on long-term business development of markets (social and economic environment), future requirements and demands, and the technical characteristics of the technology. In this paper, a scenario method as part of the technology evaluation process is described, which is intended to improve the generation of this information in a structured and traceable way.

2 Technology Evaluation

The process of technology evaluation at AIRBUS is intended to put the benefit of an individual technology into an overall aircraft context at a comparable basis. To cover the full set of effects associated with it, a cost-benefit analysis for manufacturer and operator is computed. This process comprises a technical assessment, an economic evaluation and a risk analysis.

3 Risk Analysis

Trying to obtain a prediction of the benefits of a technology for a far future is most obvious subject to uncertainty. Two major areas of risk are dealt with while carrying out AIRBUS' technology evaluation process:

- the technology inherent risk – any risk that arises out of the development, industrialization and use of a technology in an aircraft
- the risk of changing targets, requirements and environment for the application on future aircraft

It is the later risk that shall be tackled with the scenario method described here.

For the technology inherent risk, two complementary approaches are established. First, an identification of the risks throughout the life of the technology is initiated. Even though this list of risks cannot be complete, it does allow an estimation of the capability of a

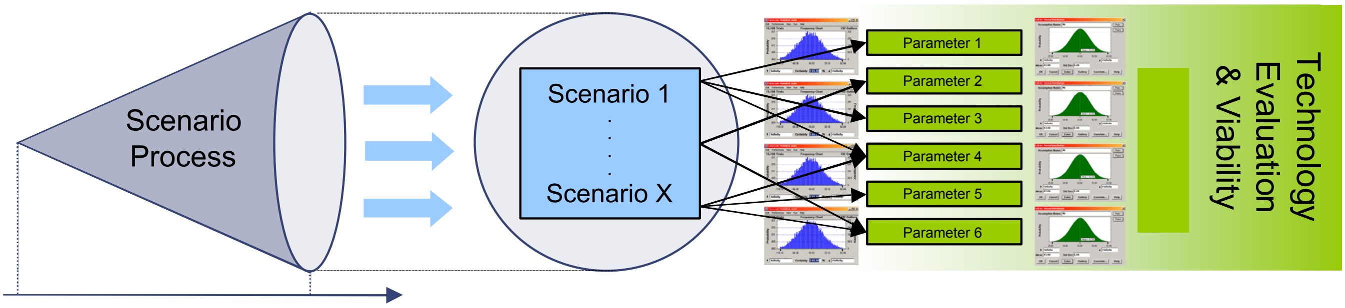


Fig. 1 Scheme of Scenario Based Technology Evaluation

technology to achieve its targets. Furthermore, it is a starting point for an accompanying risk management.

Second, the relevant parameters of a technology in the context of technical and economic evaluation are identified and the uncertainty of these parameters can be quantified. This is done in the form of probability distributions derived from experts' discussions. Once the uncertainty has been modeled, a Monte-Carlo-Simulation is run using the same models as for the deterministic technical and economic evaluation.

The scenario process described here is used to identify and quantify the uncertainties stemming from the future environmental conditions, targets and requirements for future products. From the metrics oriented scenario process probability distributions for the scenario descriptors are derived that are used to feed the quantitative risk analysis of the technology evaluation process (Fig. 1). This approach allows using the same simulation techniques for technology inherent and targeting related risks.

4 The Conventional Scenario Process

The conventional scenario approach starts with a description of the relevant parameters for the problem under consideration. For each of these parameters that will later characterize a scenario, a bandwidth of possible future outcomes is chosen. The participants of a scenario process are then asked to give a-priori estimates of the probability of occurrence of each state of parameter. In a subsequent step, a Cross-Impact-Matrix (CI-Matrix) is created that qualitatively describes the interdependencies between the parameters. Both a-priori estimates and CI-Matrix are then transferred by a calculation method into a-posteriori probabilities that build the basis for multiple scenarios (method of conditional probabilities).

This scenario process, conducted with a group of experts in a workshop format, is comprised of eight steps (Fig. 2):

Step 1: Define Focal Issue

In the first step, the workshop participants define the focal issue to be investigated in the scenario process — the specific topic, its geographical scope, and the time horizon. This issue definition sets the parameters for step two, the selection of key factors (premises and descriptors), as well as the nature of the scenario descriptions that are created in step five.

Step 2: Identify Premises and Descriptors

In step two, the participants identify the key factors that will shape the focal issue. Following a group brainstorming session to generate an initial list, these factors are categorized, prioritized, and separated into premises and descriptors. Premises are treated as given in the scenario process. Those factors for which multiple outcomes are possible (e.g., energy prices could increase, decrease, or remain stable), are called descriptors. They are treated as variables in the scenario process.

Step 3: Define Key Factors; Project Descriptors

In step three, the participants precisely define the premises, assess their current status, and give the reasons for their future

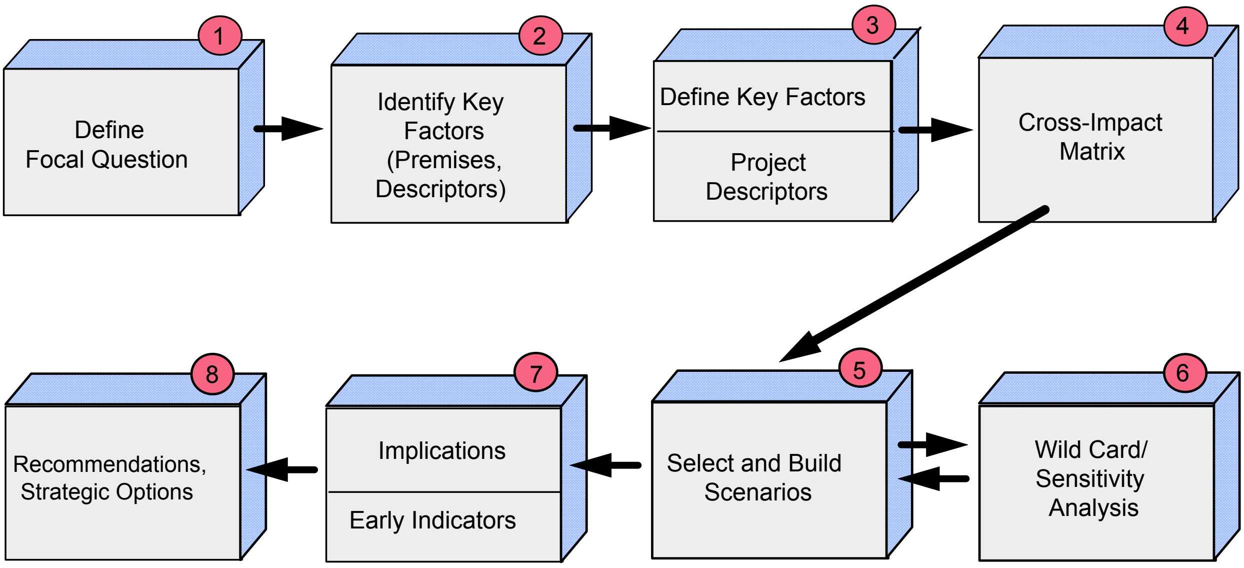


Fig. 2 The Eight Scenario Steps

development. They also precisely define the descriptors and assess their current status. After this, they make projections about the likelihood of each of the possible outcomes occurring and provide the reasoning behind each of these projections.

Step 4: Perform Cross-Impact Analysis

In order to construct internally consistent scenarios, it is necessary to first determine if and to what degree the descriptors influence one another. In step four, therefore, the participants use a cross-impact matrix to examine the interrelationship between each pair of descriptors, quantifying the degree of influence on a scale from strongly negative to strongly positive.

Step 5: Select and Build Scenarios

After analyzing the cross-impact matrix input, the STRG Scenario Tool generates data that enable the workshop participants to accomplish two tasks:

- Descriptor Reassessment: One goal of the scenario process is to assess how individual descriptors change once their interrelationships with one another are taken into account in the cross-impact matrix.
- Scenario Selection: The goal of the selection process is to obtain a diverse set of two to four plausible scenarios against which the workshop participants can assess the implications and strategic options in steps 7 and 8. While there is no fixed rule for selecting the scenarios, three criteria serve as general guidelines: frequency, internal consistency, and variety. The Scenario Tool generates the following data, which serve as the foundation for the participants' final selection.

The second scenario often has a very different, though equally realistic set of descriptor outcomes. The third and/or fourth scenarios, if chosen, generally contain elements that are either surprising, unusual, or threatening to the company. Frequently, these scenarios contain a disruptive event, or wild card (see Step 6 below).

Once the participants choose their scenarios, their task is to transform them from a list of descriptor projections into descriptions or stories that are both realistic and accessible to people who did not take part in the scenario process.

Step 6: Conduct Wild Card/Sensitivity Analysis:

Once the participants have developed their scenarios, step six is used to test how the scenarios change when a descriptor projection or cross-impact analysis is altered. This is known as a sensitivity analysis, for it checks the sensitivity of the scenario to changes in its internal makeup. In addition, external or disruptive events can be introduced into the scenarios (by inclusion in the cross-impact matrix) to see how they change the descriptor outcomes. These discontinuities, known as wild cards, are developments whose likelihood of occurrence is less than 10%, but whose impact on the focal issue would be very high. If the wild cards or new descriptor projections have a surprising and/or significant impact, the participants can use them to create new scenarios.

Step 7: Implications/Early Indicators:

In Step 7, the participants first construct a set of early indicators for each scenario to assist in monitoring which of the scenarios is actually evolving in the forthcoming years. Using the projection from the most important descriptors in each scenario, the participants identify one or more indicators of this projection and establish a threshold measure, which, if crossed, would indicate that the projection is becoming a reality. From these early indicators, it is possible to construct an "early warning system." In the other component of Step 7, the participants assess the implications of each scenario for their industry, their company strategy, or a specific product. In addition to the scenario-specific implications, implications that apply across several or all scenarios are also of significance.

Step 8: Assess Strategic Options; Make Recommendations

In the final step of the scenario process, participants assess the strategic options available to the company and, depending upon the larger context in which the scenario process is done, may make specific recommendations about future company actions. Ideally, the participants will derive a "robust" strategy from the scenarios; that is, a strategy that would work well in any of the possible futures or at least to be flexible enough to adapt to any of them on short notice.

5 Modifications in the Scenario Process

For the use of the scenarios process described above for technology evaluation, some of its steps have been modified, others had to be disconnected to either pre- or post processing. Especially the last two steps (7 and 8) are of minor importance in this context.

To cope with the demand for agreed and consistent parameters for technology evaluation, thee elements are introduced into the scenario method:

- the definition of strictly metrics oriented parameters (a quantified description rather than a qualitative one),
- the split of the parameters (and the CI-Matrix) into global, intermediate and local factors and
- the transformation of the scenario parameters into probability distributions for quantitative risk analysis.

5.1 Quantifiable Descriptors

The technology evaluation at AIRBUS is based on technical and economic simulation of the effects of the technology at aircraft level. The underlying models require of course the input of the parameters describing a scenario in scalar variables or in the case of quantitative risk analysis in the form of probability distributions.

As traditional scenario processes do not necessarily need this precision in the definition of their descriptors, a special focus has to be set on the generation of quantified descriptors in this approach in step 3 of the above process.

Once having identified the relevant premises and descriptors in step 2, it is necessary to translate these into representative metrics. These metrics have to fulfill multiple criteria. They should be continuous, explicit and well defined.

To illustrate the generation of quantifiable descriptors an example shall be given. In a scenario process, the participants identified the descriptor "International Political Stability" to take into account the state of balance of political power. It embraces the political situation that changes in the frame of economic and politic transformation processes between different groups of interest.

The metrics identified for this descriptor

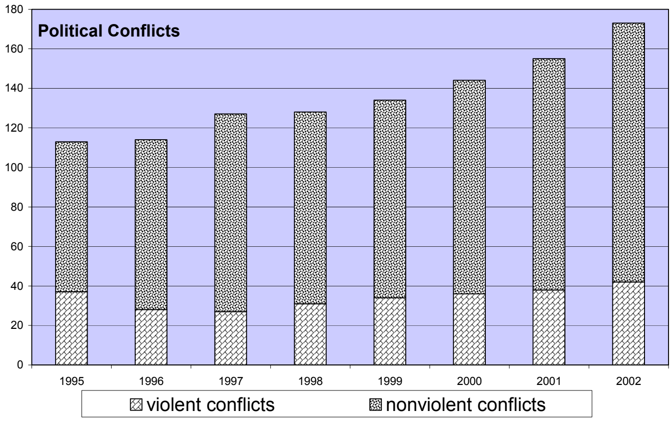


Fig.3 Average No. of Conflicts Worldwide p.a. [1]

was the number of political conflicts per year. Statistical data was available for the last decade (Fig. 3, [1]), so a baseline definition could be derived including a "state-of-the-art" statement. In the course of the process, qualitative projections ("more stability", "as today", "less stability") could be transformed into quantified metrics.

From this statement of the current situation, the definition and three projections were derived:

- decreasing no. of conflicts (100 – 140 conflicts per year)
- stagnating no. of conflicts (140 – 180 conflicts per year)
- increasing no. of conflicts (180 – 220 conflicts per year)

Even though the bandwidth for the projections does not directly go into the models for technology evaluation, the quantification allows to track the evolution of the perception over time and a constant update with newly available statistical data.

For the task of transformation of qualitative to quantitative descriptors, three different techniques have been used and found useful:

- deriving the descriptor directly from the calling models or programs,
- asking experts in the relevant field for their input,
- searching the Internet for the keywords and analyzing the associated metrics.

As this procedure requires considerable time, most of the parameters have to be prepared prior to the workshops and are offered to the participants to choose from. This way of working puts additional load on the preparation team and has to be performed quite carefully in order not to bias the results. Another solution would be to break after step 2 and to perform the necessary analysis offline.

5.2 Cascade approach

For the method described here, the describing parameters are grouped in three areas: the macro factors are related to the global socio economic environment, the meso factors cover air transport in general and the micro factors are specific to aircraft requirements and technology impacts (Fig. 4).

It is assumed that only the "upper level" environment factors will influence the "lower level" factors. This goes along with a requirement driven perception of the air transport industry and the aircraft manufacture. It is recognized that different concepts of the influence of air transport on the economy exist (e.g. new routes generating additional economic growth) but these are considered to be of minor interest in more global scenarios. Nevertheless, they might be of importance if a more local focus for the problem definition is chosen.

As the CI analysis becomes very time consuming with the number of parameters neglecting one third of all possible

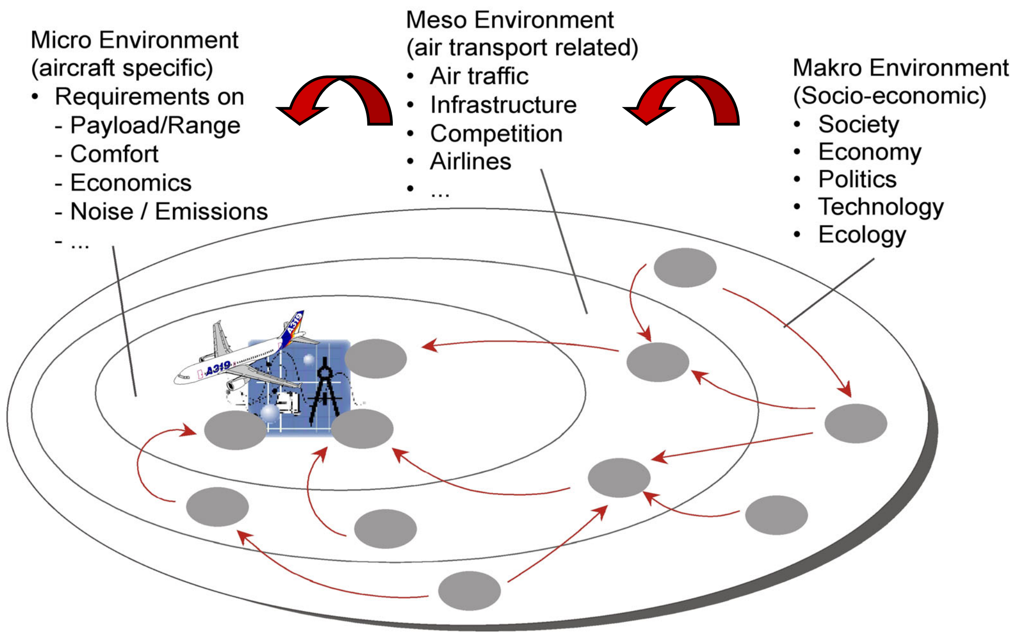


Fig. 4 Cascade of Scenario Factors

interdependencies results in a considerable reduction of effort.

The concept of splitting or cascading the scenario descriptors into global, intermediate and local factors (or macro, meso and micro factors) takes into account the fact that in general, it is difficult to unite experts for all aspects of the complex scenarios at one time and at one place for discussion. It was obvious at several processes that political economists are not too comfortable in the generation of projections on aircraft approach speed as aeronautical engineers are not with GDP prediction.

The building-block structure also allows integrating already existing scenarios (e.g. Europe's Vision 2020 on air transport) into a more detailed and still consistent view on specific aspects of technology and project evaluation. It can be assumed that the global view from the macro environment may remain constant while meso and specifically micro environment factors are subject to adaptation to the technologies under consideration. Within a single scenario process the number of factors is limited to a maximum around 30 for practical reasons. Considering the wide set of potential requirements for a technology evaluation out of the micro environment it is obvious that different scenario processes have to be conducted. The cascades approach allows to integrate the more detailed "lower level" approaches into a single, common overall scenario picture.

5.3 Evaluation of Cross-Impact Matrix

A generation of a CI-Matrix that can be altered and updated throughout the process of scenario generation can be looked upon as a basic model of interdependencies between the factors that describe a scenario.

In order to construct internally consistent scenarios, its first necessary to determine if and to what degree the variables influence one another. The experts use a Cross-Impact-Matrix to examine the interrelationships between each pair of variables, quantifying the degree of influence on a scale from strongly negative to strongly positive.

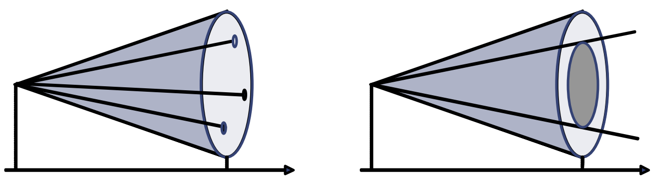
Even though it is based on more qualitative relations, it is shown that it gives a good first rationale for the selection of relevant drivers of future developments and the stability or robustness of the scenarios derived from. Key question for cross-impact analysis:

- *How will the probability of occurrence of the respective state of* *(row-) variable Y be changed if the respective state of (column-) variable X occurs?*

A scenario is always calculated under the assumption that one certain future projection of a variable occurs, i.e. that the probability of this variable is equal to 100 percent. From this starting point the probabilities of all other variables will be recalculated according to the matrix values and the scenario tool generates the entire range of possible future scenarios. Each of these skeletal scenarios is comprised of different combinations of descriptor outcomes.

In conventional scenario projects (Fig. 5a) single scenarios or scenario cluster were generated to have a sufficient spectrum of possible future outcomes. Technology evaluation was only conducted on single incidents and situations.

In this continuative approach (Fig. 5b) additional statements to the entire scenario spectrum and certain factors are computed (in the form of probability distribution).



a b

Fig. 5 Scenario Clusters (a) and Scenario Spectrum (b)

From the results of the scenario tool a single probability distribution can be derived for every variable to isolate the start input for the risk assessment of product and technology evaluation (Fig. 6).

Using the same process for either generation of single scenarios and spectrums of projections allows to analyze in the more abstract way of quantitative risk analysis and to compare that analysis with the well defined consistent scenarios. An assessment of robustness can be made either way and may complement each other.

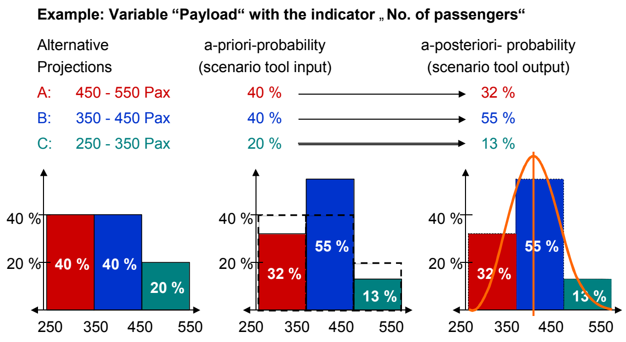


Fig. 6 Probability Distributions for Descriptors

5.4 Descriptor Bandwidths for Risk Analysis

Once having spectrums for the projections at hand, the probability distributions can be used to initiate a numerical risk analysis. Describing the uncertainty of some boundary conditions in the economic evaluation and assessing their effects with Monte-Carlo Analysis then gives an indication of the robustness of a technology under uncertain future targets.

6 Example of Application

To cope with the challenges of future air transport and to identify promising technologies and concepts some "out-of-the-box" thinking becomes necessary. For this exercise, AIRBUS has created a set of unconventional configurations to explore capabilities and to meet more demanding targets [2].

Different scenarios were created that were set up under different paradigms to drive certain requirements and to open the associated design spaces. To assess each configuration in the relevant context, not only the primary drivers had to be determined but a consistent environment (comparable but distinguished from the current evaluation models) needed to be created. These scenarios were then used to compare different configurations (Fig. 7). Without going into details of the evaluation as such, it can be seen that the effects of different

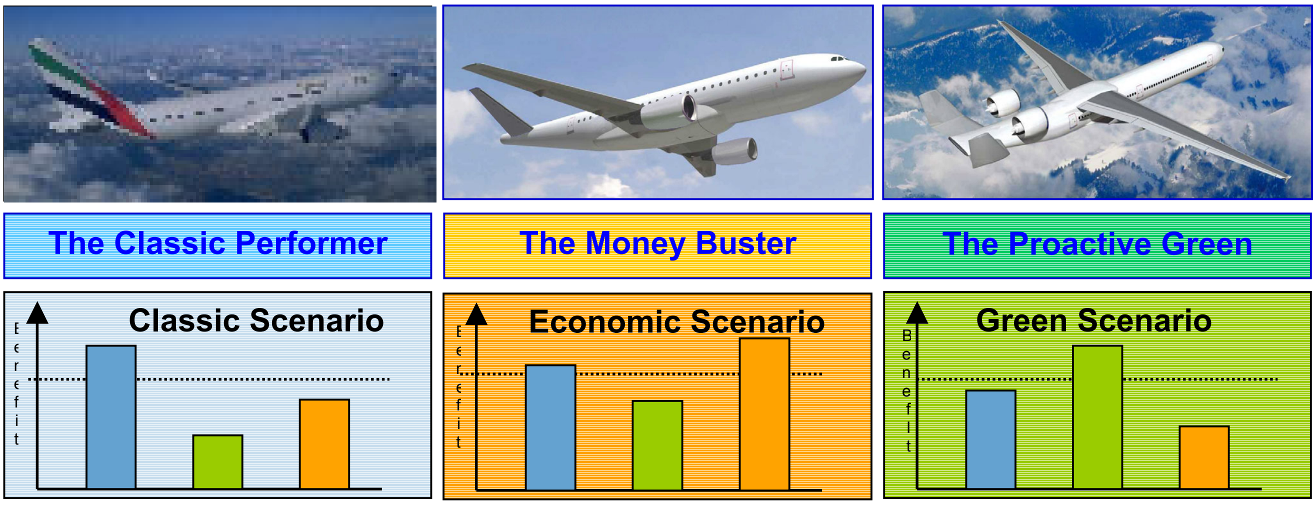


Fig. 7 Comparison of Aircraft Concepts in Different Scenarios

scenarios had a significant impact on the benefit assessment of the technologies.

6 Conclusion

Due to the long term of projections necessary and the high degree of uncertainty associated, the input parameters required to perform the technology evaluation are difficult to obtain. Even when it is not possible to improve the accuracy of the predictions, a structured and repeatable, cascaded approach using a metrics oriented scenario process is a way to get a higher quality of analysis as well as an enhanced common understanding.

The use of scenario processes in technology and project evaluation has to go along with methodologies in decision and policy making (e.g. Vision 2020, ASTERA). Breaking up the process in several cascaded environments and generating an expandable CI Matrix supports this approach.

A further issue is the necessity of an improved understanding of the effects of the scenario uncertainty on the deterministic technology evaluation. Here is the challenge on the interpretation of the results.

With the here described method of the integration of a scenario process into technology evaluation a procedure to better understand and more efficiently guide technology development is available. The communication of the rationale and trade factors used for optimization in different scenarios is improved. Still, some aspects of the interpretation of mathematical formulation and interpretation of probable results are subject to further investigation.

7 References

[1] Heidelberg Institute of International Conflict Research HIIK, 2003 (http://www.hiik.de/de/index_d.htm)

[2] Y. Vigneron, "Commercial Aircraft for the 21st Century: A380 and Beyond", AIAA/ICAS Air & Space Symposium and Exposition, Dayton 2003