

# STRUCTURED APPROACH TO THE DESIGN OF TEST CAMPAIGNS

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## Abstract

We have analyzed the similarity between new product or service development and the design of test campaigns in the field of aircraft propulsion systems. In analogy to new products, test rigs have a distinct life cycle. The design of test campaigns as well as the design of new products or services has to be driven by customer requirements. The test rig, the test bed, the instrumentation, data reduction and the analysis methods including the resulting correlations become part of such a test campaign. We have recognized that the customers and their requirements can be clustered resulting in specific types of experiments. In analogy to new product development we found that capturing and structuring the voice of the customer is a challenge. Methods from the design for six sigma tool box like KJ Analysis and Kano Analysis turned out to be extremely helpful. We used Quality Function Deployment for the translation of new, unique and difficult requirements into a specification of the experiment. Rough cut concepts have been selected using Pugh Concept Selection and Pugh Concept Scoring.

## NOMENCLATURE

PCS	Pugh Concept Scoring/Selecting
PM	Performance Measure
QFD	Quality Function Deployment
VOC	Voice of (the) Customer

## 1 INTRODUCTION

Aerospace research and development is characterized by strong links between analytical and experimental work. Hence organizations in this field repeatedly are faced with the tasks to carry out test campaigns. Typically the cost involved with testing activities is high. Therefore structured approaches have been established to plan and perform tests with the aim to increase efficiency and thus to reduce the cost incurred. Engine development programs and component development programs are prominent examples of such planning activities. The processes involved are repeatedly run through for every new product. At first sight experimental basic research does not seem to fit such processes. Experience in our research activities has shown that especially new, unique and difficult experiments require careful planning, performing and analysis. In our view it is possible to standardize this process and hence to improve the quality and consistency of the outcome. Regarding a test campaign similar to a product or service helps in this context.

## 2 SIMILARITY BETWEEN A TEST CAMPAIGN AND A PRODUCT OR SERVICE

All people involved in product or service design must anticipate what the customers are looking for. It has to be understood how customers balance value proposition and price. This is a challenge which is unique for every industry and even unique for every product or service. The main values expressing this balance have to be judged from the customer perspective. According to [1] they are:

1. Performability
2. Affordability
3. Featureability
4. Deliverability
5. Usability
6. Maintainability
7. Durability
8. Imageability

For a test campaign the customer is the engineer who is tasked to gain insight into a complicated engineering problem. Values (1) to (8) have to be judged out of this engineer's perspective. This involves defining the required insight as precisely as possible. Furthermore it requires understanding the methods of analysis available such that the use of the information generated by the experiment is transparent. From this point of view performability means for a test campaign that all

required information or data is generated in the quality required by the users of this information. Affordability comes down to the cost of the campaign being within the budget assigned. Featurability is understood as the provision of addition value such as any information or experience which helps beyond the defined test targets. Deliverability means that the data required from the test campaign are available for the internal customer when it is needed. Usability expresses the easiness to use the generated data. This includes the format and data structure. The term maintainability needs some stretching in this context. It can be interpreted such that hardware and software required for a test campaign can be kept in use easily. Durability means that all hardware and software as well as the data can withstand abuse. We have found that some organizations ensure that also their experimental work fits an image of quality and prestige. This would be imageability.

It becomes obvious that a test campaign can be regarded similarly to a highly individualized one-off product produced by a job shop rather than line manufacturing. At this point it is important to recognize that the term test campaign embraces

Tab. 1: Modules Defining a Test Campaign

- Test vehicle
- Test bed
- Instrumentation and data acquisition
- Test procedure (Specification)
- Analysis methods

In the likely circumstance of reoccurring tests using the same test bed, test vehicle, and instrumentation with only minor adjustments, we conclude a test campaign's requirement for adaptability or modularity. A product equivalent for such a series of closely related test campaigns would therefore be defined as individualized small scale product. For such products, the structural planning method implements fundamental requirements and product functions rather than detailed solutions. It identifies product parts that do not change during production and parts that can be varied according to customer demand and the respective intra-product interfaces required to do so [3].

### 3 DESIGN SEQUENCE

We propose a structured approach to the design of test campaigns consisting of 3 major steps. An overview of product development methods that will be used for test campaign development is illustrated in Fig. 1. The different steps will be pointed out in more detail in the sections below.

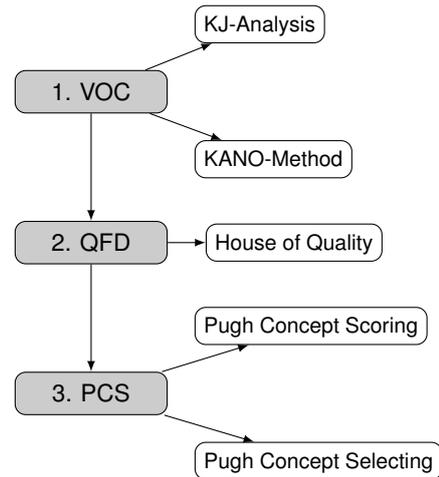


Fig. 1: Product development methods used for the structured approach to the design of test campaigns

In the first step of test campaign design it is necessary to find out who the customer is and what finding he is interested in. This process can be described as gathering the voice of the customer (VOC). The requirements formulated at this point in time might be expressed in very general terms. As the second step we use quality function deployment (QFD) to translate the voice of the customer into performance measures (PM) for the test campaign. In this step all new, unique and difficult requirements are translated into measurable engineering criteria. These form a vital part of the specification for the modules described in Tab. 1. In the third step all possible design concepts will be generated and evaluated against the product PMs defined in the second step. Here we use Pugh Concept Scoring and Pugh Concept Selection (PCS) to identify the best concept. Once a design concept is selected, detailed design of the modules in Tab. 1 can begin using the PMs defined during the process.

#### 3.1 Gathering the voice of the customer

A variety of reasons exist to start a test campaign. Gathering the VOC therefore starts with a classification of the type of test campaign. In general we found five basic segments of tests (see Fig. 2). Tests to describe phenomena are carried out mostly during basic research projects. Tests generating correlations or even supporting numerical simulations are a vital part of the method development. Validation and compliance tests always are part of an engine or component development program. It becomes obvious that each of these test segments serve different customers having special requirements. This seems to be an obvious

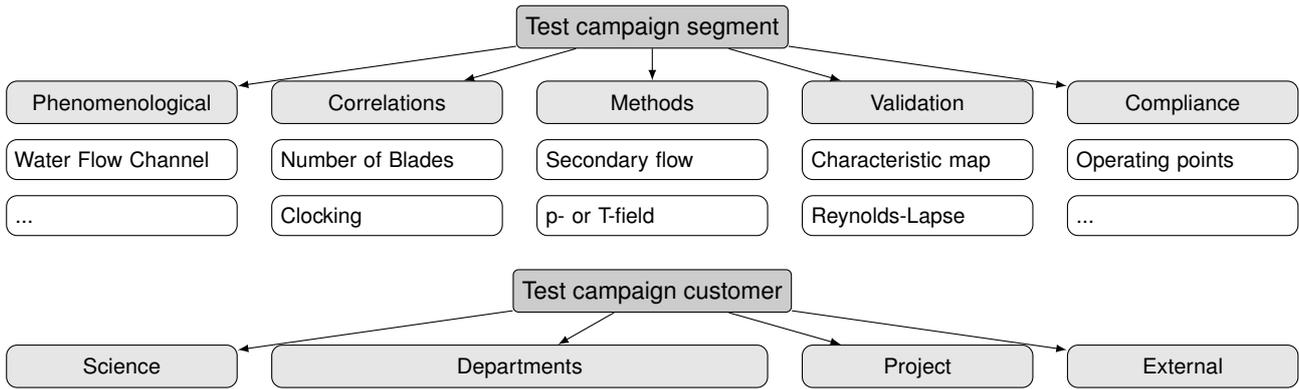


Fig. 2: Different test campaign segments for different customers will result in different requirements for the same type of test campaign

thing. In our experience being aware of this helps significantly in designing the best test possible.

With the customer segment specified, customer requirements can be collected, reduced and structured. Most requirements expressed by the customer do not represent the actual desire of the customer but express what he thinks the outcome of the test campaign should be like. For a successful test it is therefore essential to convert the customer requirements into credible requirements for the test campaign. We chose the KJ Method for structuring and the Kano Model for weighting all gathered requirements.

**KJ-Method**

The KJ-Method, named after the inventor Jiro Kawakita, is used to structure the VOC by means of 3 steps. The first step is to bring all VOC elements on the same level of detail. In the second step, elements are arranged with regards to their content. Third, umbrella terms are defined for each set of grouped elements [5].

**KANO Model**

The KANO model is used to assess the importance of each element of the VOC. Kano implies that not each VOC-element has the same importance to the customer but can be assigned to one of three different quality categories [2]. By asking a functional and dysfunctional question for each customer requirement it can be identified as attractive, one-dimensional, or must-be quality. This is expressed as ratio of customer perception to state of physical fulfillment, see Fig. 3.

The most obvious “must be quality” within test campaigns is a safe test operation. An unsafe test environment will result in dissatisfied customers, however a safe test will not lead to customer satisfaction as it is naturally implied by the customer. Examples for

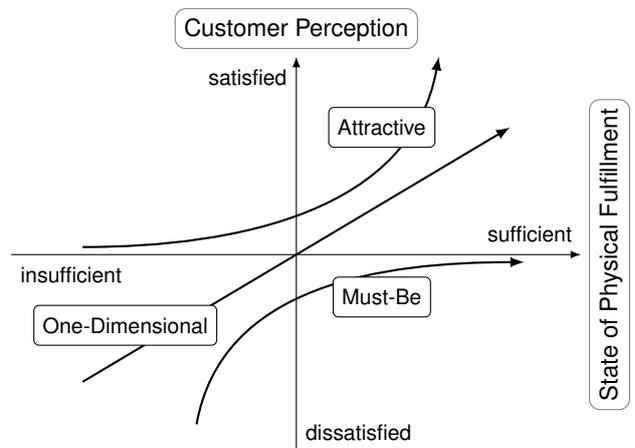


Fig. 3: The KANO model based on [2]

one-dimensional quality could be the extent of offered operating range (the greater the better) and for attractive quality the possibility of unforeseen change of measurement equipment and position (flexibility) during test procedure.

**3.2 Translating the voice of the customer into performance measures**

In the second step the VOC is translated into product PMs that can be physically judged or measured. The most powerful tool of the quality function deployment approach for the translation of the VOC into the voice of the engineer is called the House of Quality. Being a matrix it contains customer requirements in the rows and PMs in the columns and thus easily visualizes interdependencies between them. At the same time it identifies interdependencies of PMs in both positive or negative ways. At each row-column intersection the influence of the PM onto the customer requirement is assessed to be none (0), weak (1), medium (3), or strong (9). More information can be added to each PM by stating the

direction of improvement and its technical complexity on a rank from 1 to 9. Multiplication of the customer requirement importance with each row/column intersection value then gives a relative PM value that is used to rank the PM according to the VOC. This allows for reasonable development time distribution to achieve optimal customer satisfaction [5].

### 3.3 Pugh Concept Scoring and Selection of test campaign concepts

The scoring and selection method proposed by [4] again uses a comparative matrix of all concepts to identify weaknesses and strengths of each concept with regards to each performance measure identified. To do so, PCS requires a base scenario to which all generated concepts are compared to; preferably an existing concept is chosen as base scenario, however any concept is likewise applicable for the process start. By comparing each concept element against the base scenario, eventually a better concept is identified. For the next iteration, this concept becomes the new base scenario. To make full use of the PCS method, more concepts are created during the process by combining the "better than base scenario"-elements of different concepts to a new concept superior to the donor scenarios. The whole process is rerun until no new concepts can be generated and one concept is better than all other concepts.

## 4 CONCLUSION

With the design sequence for the structured approach to the design of test campaigns defined it is now pos-

sible to apply this 3-step-method onto any new test campaign planned at the Institute for Aircraft Propulsion Systems in Stuttgart. It will allow for faster and more efficient realization of research projects that comprise test campaigns of any scale, leading to improved satisfaction of both researchers and customers.

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