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 informa-
tion 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 inter-
preted 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 re-
garded similarly to a highly individualized one-off prod-
uct produced by a job shop rather than line manufac-
turing. 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 cam-
paign’s requirement for adaptability or modularity. A
product equivalent for such a series of closely related
test campaigns would therefore be defined as individu-
alyzed small scale product. For such products, the
structural planning method implements fundamental
requirements and product functions rather than de-
tailed solutions. It identifies product parts that do not
change during production and parts that can be var-
ied 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.

In the first step of test campaign design it is neces-
sary 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 measur-
able 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 de-
dined 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 classifica-
tion of the type of test campaign. In general we found
five basic segments of tests (see Fig. 2). Tests to de-
scribe 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 compli-
ance tests always are part of an engine or component
development program. It becomes obvious that each
of these test segments serve different customers hav-
ing 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.

**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 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 interactions 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

![Figure 3: The KANO model based on [2]](image-url)
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 possible 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 researches and customers.

REFERENCES


