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PRODUCT DESIGN AS AN INTEGRAL PART OF ENGINEERING DESIGN – PROCEDURE PLANNING FOR THE DESIGN PROCESS

Uhlmann, Johannes[1], Krzywinski, Jens[1]
[1]Technische Universität Dresden, Industrial Design Chair, Dresden, Germany

ABSTRACT
Product design is one of many fields in which the word design is used. Our every-day work, research and teaching in the field of product design is marked by the designing and styling of largely technically determined objects. Although product design belongs to the engineering designer's most important partners in product development, there are still preventable difficulties between the two fields that hinder an efficient cooperation with a division of labour.
In this paper we will present a procedure planning for the design process, which is an integral part of the engineering design methodology according to VDI 2221. This procedure planning is based on a design theory and definition which focuses on the concept of *experiencing* products. Methodically, this procedure planning orientates to the psychic regulation of action, e. g. it orientates to the human mind.
The phases of this procedure planning will be explained in detail. Figures showing the design process of a microlight aircraft, developed by the author, will exemplarily illustrate these phases.

Keywords: design methodology, design process, engineering and product design collaboration, experiencing, Action Regulation Theory

1 CONFLICT BETWEEN ENGINEERING AND PRODUCT DESIGN
Product design is one of many fields in which the word *design* is used (engineering and product design, graphic design, fashion, media, software design, etc.). Our every-day work, research and teaching in the field of product design is marked by the designing and styling of largely technically determined objects. Its realm is within machine, plant and device design.
Although product design, and other relevant design fields, belongs to the engineering designer's most important partners in product development, there are still preventable difficulties between the two fields that hinder an efficient cooperation with a division of labour. From an engineer's perspective, there may be design development goals which are not plausible and which complicate the engineer's methods for reaching his goals. Interestingly, there have been many attempts to develop design methods with the intention of integration into engineering design methods. A partial overview can be found in [1]. Just as the "methodology for developing and constructing technical systems and products" [2] and "general procedures" ([3], p. 21) can be seen as a compendium of all engineering design methodological efforts, the VDI Guideline Industrial Design serves the same purpose for design [4]. This guideline was published in 1986 and 1988. It is the continuation of the guidelines *"Formgebung technischer Erzeugnisse"* and the last publication in the series. The attempt to methodologically integrate design into engineering design methodology was abandoned in the design guideline. The original purpose, a systematic and methodical design process suitable to engineering design methodology, could not be achieved. "It is apparent that we are on the right path, but the topic is so complex and comprehensive that the existing version seems to be enough to publish" ([4], sheet 3, p. 3).
Looking at international research publications, the conflict between both disciplines seems less evident. Due to the missing linguistic separation and the common scientific engineering and industrial design research at the same research institutions there is a variety of overlapping contents and common approaches. Particularly relevant authors in this field are Cross [5, 6], Lawson [7, 8], Cagan & Vogel [9], Roozenburg [10] among others.

A summary of design's position within engineering design from literature on engineering design shows that there are two allocations, as in Figure 1. According to Figure 1, engineering design is responsible for the realisation of functional technical solutions to the commission. In the second allocation, within the phases 5 and 6, design assumes the task of determining form, colour and surface, as parts of what is called styling requirements, of technical objects. Because prescriptive rules are often available for requirements, such rules are also expected of design. However, these cannot be given in a responsible and suitable form, which explains the 'design scene's' lack of involvement over the years.

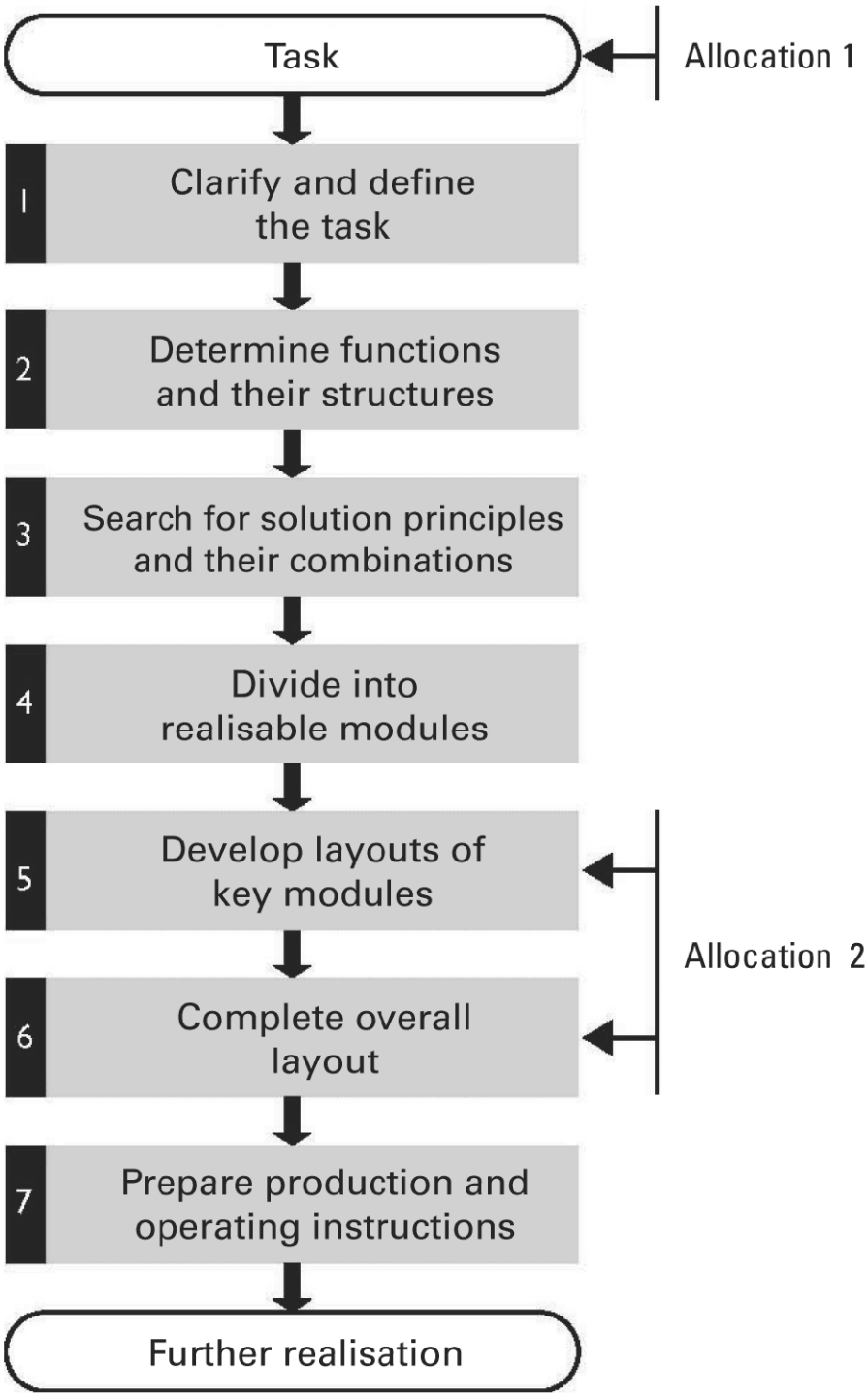

Figure 1. The allocation of design in engineering design methodology

Allocation 1 assumes that design visuals should be seen as an earnest base for engineering even before the start of development. In this case, these visuals cannot afford to be just pretty pictures. One can admit, however, that design can be granted an important function for innovative products in engineering design product planning [11].

One easily gets the impression that design does not belong to engineering design. For technical and functional solutions it is meaningless, and according to the current engineering design methods, design has, if at all, a bothersome influence. This view contradicts the work of independent design studios, whose service palette includes the development of technical products. Especially in the early stages of product development, technical conceptualisation is a part of design work. A strict separation between technical and design development is not possible in design studios with complete development services or in design departments of larger firms (Figure 2). Certain is that the deciding authority about the correctness of technical solutions will remain the domain of engineering design

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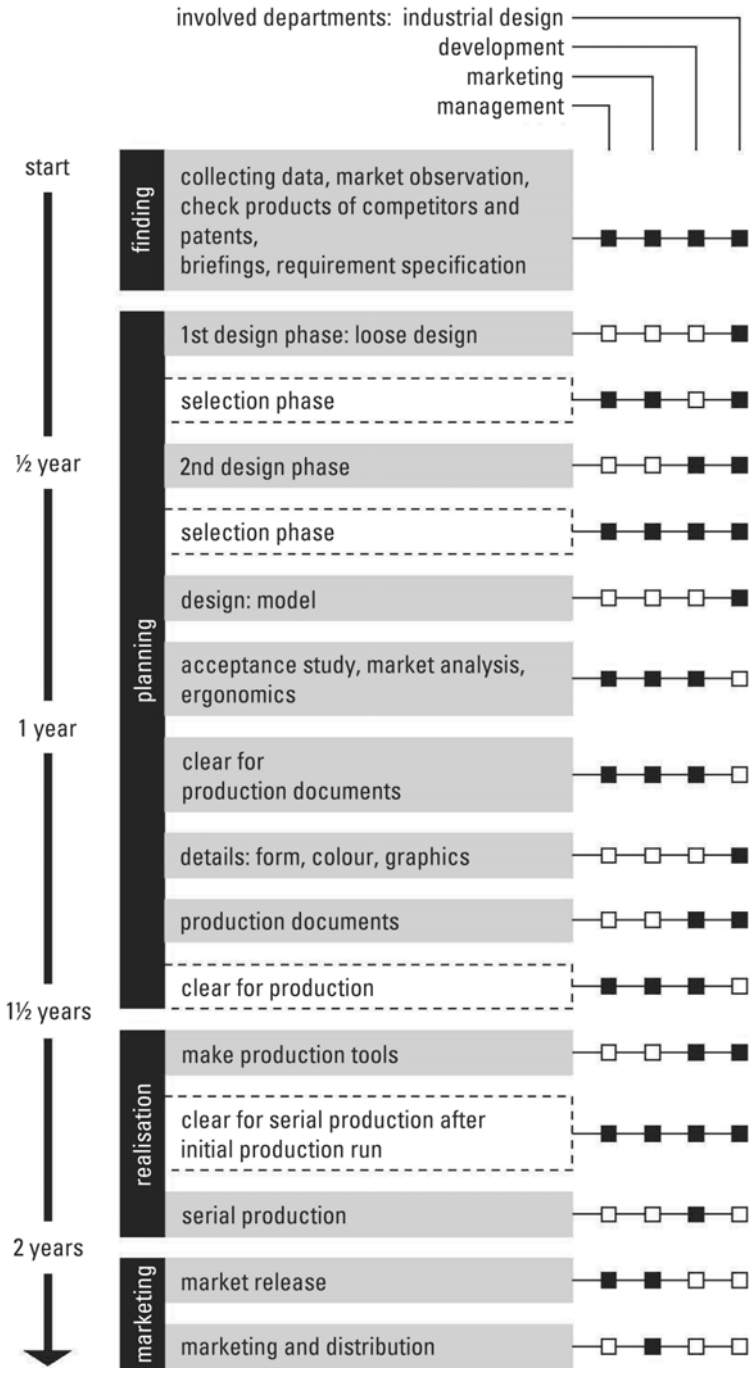

Figure 2. Development of electrical hand tools at Bosch according to [12]

2 FUNDAMENTALS OF PROCEDURE PLANNING FOR THE DESIGN PROCESS

The novelty about the procedure planning lies in the fact that this model is based on the processes in the human mind. These processes are described by the theory of the psychological action regulation [13]. The procedure planning is based on empirical investigations about the ingenuous design processes of expert designers.

The action regulation theory formally describes the psychological regulation procedures in the mind, whereas it does not consider concrete contents yet (practical, theoretical, scientific and design contents).

The fundamentals are:

- a cyclic regulation model as a comparison of nominal and actual values whereas the circular elements of the model are linked to linear action chains. This is called a cyclic-sequentially regulation of the activity.
- a hierarchically further segmentation of the cycles of an action chain, down to the smallest unit of an activity which is *action*. On all model levels the same procedures can be identified in different scale. This corresponds to the hierarchical-heterarchical nature of the action regulation.

This formal operational sequence incorporates action knowledge, which consists of all knowledge, experiences and skills regulating the entire procedure [14, 15, 16].

The term *experiencing* technical objects is also important to procedure planning for the design process and its underlying design definition. *Experiencing* is the unit of the objective and the subjective in the human mind. Objects and processes are experienced during their use.

2.1 The inception of procedure planning

Procedure planning for the design process [17] is based on results from professional product designers, as well as on personal design and styling projects for firms and in my experience as an instructor. Theoretical and scientific generalisations have their factual fundament in and will be verified by practical design and styling work. The procedure planning for the design process has primarily been for the education of novices studying product design at the Technische Universität Dresden. One can assume that successful design experts act more or less intuitively according to these measures. The planning is empirically supported and corresponds to an action-regulatory optimal and barrier-free process.

2.2 Determining procedure planning

Procedure planning for the design process is a design methodology for technical objects that suits to the established, acknowledged and (in German-speaking areas) the most widely spread engineering design methodology according to the VDI Guideline 2221. Procedure planning for the design process can be interlaced with the engineering design methods, as schematically depicted in Figure 3. Current research and development projects, also applicable for the industry, offer further verification.

Although the engineering design methodology according to VDI 2221 is a prescriptive idealisation ([18], p.4) of the actual engineering process and in praxis, the work itself deviates from it [19, 20, 21], it is used for the procedure planning for the design process because of the lack of a more appropriate, thorough and extensive methodology.

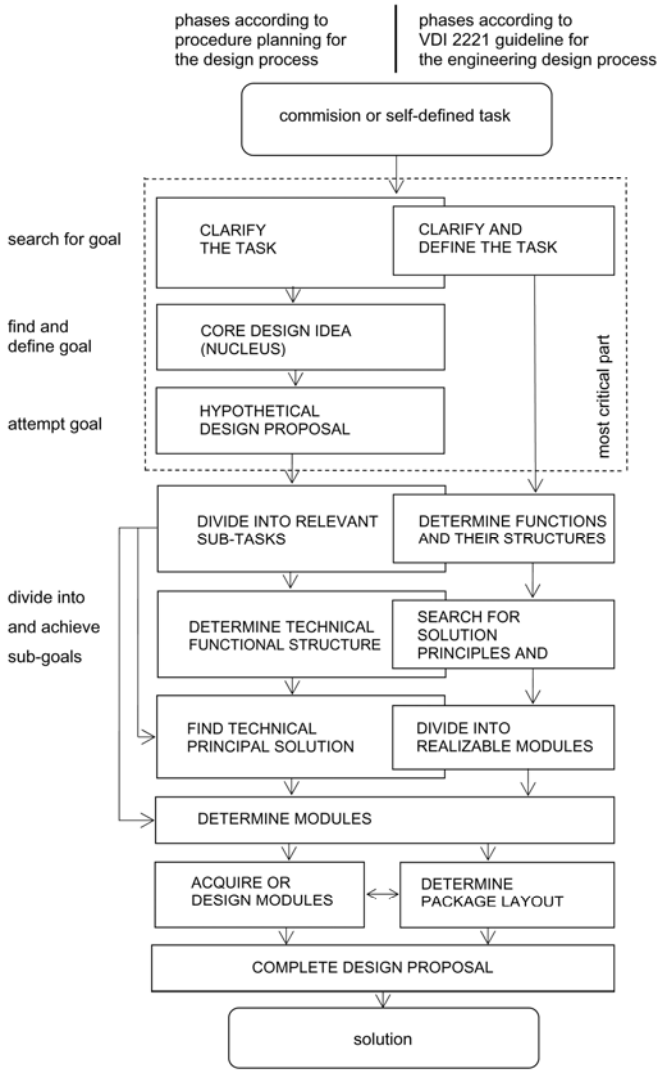

Figure 3. Interlacing of procedure planning for the design process with engineering design methodology according to VDI 2221

2.3 Basic terms and fundamentals

Procedure planning originates from the designer's internal operations. It is his task to produce a solution to a commission for client use [16]. The design and styling process proceeds thereby according to the human psyche, according to non-voluntary regulatory mechanisms that are superordinate to the content of the design task. As a result, the approach for the superordinate is not only seen as an external organisational schema for communicative and planning purposes, it is also of use for insights into the psychic regulatory happenings as the most important design methodological fundament and guide. Theory and results of the so-called psychic action regulation [13, 14, 15], [22] are used as methodological tools to support design.

The equally important focus on *experiencing* technical objects and processes has been reflected in various publications [9], [23], [24], [25], [26] and others. These publications contain some similarities to the thoughts presented in this paper, in particular experiencing playing a key role in design and developing a certain product character for appropriate experiencing as a major goal of the design process.

"'What people seek is not the meaning of life but the experience of being alive.' Laurlee Alben" [25]
"Design is a core skill, […], but also as a way of thinking about 'life experience'. How we can create experiences, and how these affect human behavior and the world, both material and immaterial, is the domain of design." [25]

Experiencing is "the inner and the personal of the knowledge of humans" [27]. Experiencing is any procedure in consciousness [28]. The thinking and creating subject is the ego [29].
In the term experiencing human cognition, emotion and conation can be united as recapitulatory name for motivation, enthusiasm and will. In the term of experiencing the unit of the conative, cognitive and emotive components in the thought is expressed in the smallest element of a piece of thinking experience [28].

Experiencing is part of any human everyday life behaviour. Experiencing produce means becoming aware of the product, in order to determine its use. Consequently, the three first phases of the procedure planning deal with collecting information relevant for experiencing, with defining the nature and with its transfer into a design object.

Object design action expresses the concurrence of thought and visualisation within the unit action [30]. There is a specific design thought that is linked to object-appropriate sensomotoric executive operations such as drawing, modelling or making visualisations directly on the object itself. This thinking is not identical to verbal thought [31], [32, 33].

Suggested terms are design thought for the internal processes and visualisation action for the exteriorisation of these processes, and they are modelled as a double-helix (Figure 4) [34]. Object design action is a permanent interaction between internal thought operations and their externalisation, i.e. in the form of a sequence of drawings within a larger design process. The result of each executive operation is recycled through the sensory organs and leads to further thought processes. This sequential relationship between object design actions makes up the object design activity (see also Figure 5 and Figure 6).

“I draw in order to see what I think,” [35] is a succinct formulation of this phenomenon.

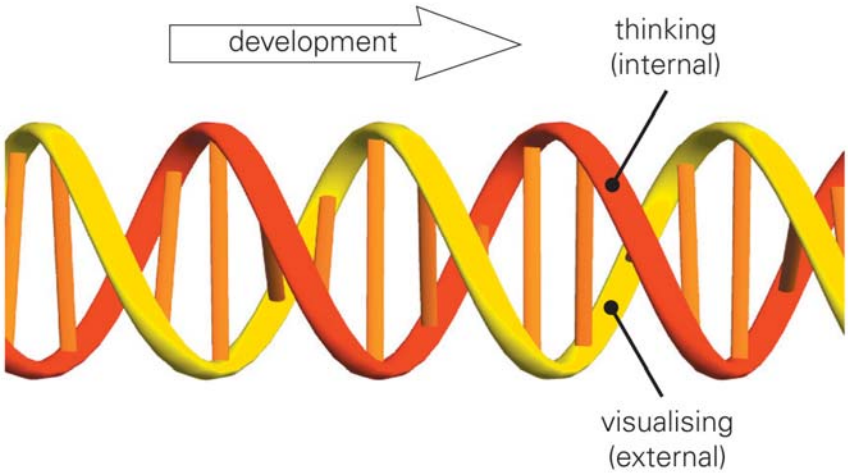

Figure 4. Object design action in a unit of thinking and visualising (thought-action) in a double-helix model, according to [19]

The term use as the content and purpose of object design and styling is an evaluative term. It comprises the anticipated subjective value of a thing, an occurrence, an action or result of an action [36]. It pertains to human *experiencing*. Experiencing, as well as behaviour, belongs to the general terms available to describe human psychic processes. Experiencing and behaviour are two moments of the action-regulating consciousness (Rubinstein, according to [37]).
Using the described terms for technical objects shows that these terms have been developed for use by an end user.

The evaluation of a technical object’s includes the evaluation of its function and the correctness of its technical solution, its safety, ergonomics and objective properties as correct (or incorrect). Simultaneously the appeal (as pleasant or unpleasant) of an object is also evaluated. Appeal is a

subjective matter and not one accessible to observation. Appeal combines subjectivity with outer and objective properties.

Subjectivity is objective to a certain extent, in that it is inherent to all people. This joint evaluation of positively accepted objective properties and subjective appeal is, according to Kant [38], "aesthetic judgement", and it occurs when there are no special demands on perception and processing. Objective correctness and subjective appeal are the most general categories for the evaluations of technical objects and their use (see Figure 5-9).

2.4 Four major components of procedure planning

The following four fundamental components of procedure planning result from a summary of the basic terms and fundamentals

- Use of the psychic regulation of actions as a methodological guideline for the design process
- Theoretical basics focussing on *experiencing* in order to enable designing products which can be positively experiences
- Object design action as a personal basic methodology and the proficiency requirement for designing
- Both criteria correctness and appeal as aspects of evaluation within the design process.

3 INSTRUMENTAL PROPERTIES OF THE PHASES OF THE PROCEDURE PLANNING

3.1 Instrumental methodology

The use of the procedure planning accompanies the design process. It does not require extensive learning methods outside of or alongside design work. Prerequisite is knowledge about the theoretical basics of procedure planning, which can be illustrated by examples. It is assumed that the designer possesses proficiencies in object design.

The thematic and formal adaptation of the procedure planning to the engineering design methodology can be found in the interlaced depiction found in Figure 3.

Due to the number of phases for design corresponding to "clarifying and defining the task", the schema in Figure 3 appears to be temporally and thematic more extensive than the engineering design schema. The separation into three phases originates from methodical and didactical considerations and is necessary with reference to the Action Regulation Theory, although for an experienced designer, these three could possibly be observed as only one phase.

3.2 Knowledge inventory in phase 1: *Clarify the task*

This phase begins when an impersonal development commission becomes a personally redefined task. A commission differs from a task in that it is an economic and judicial unit independent of the designing person [13]. With respect to an undefined goal, *clarify the task* includes sifting through the memory for knowledge that will, in accordance with the commission, lead to a goal. This includes the inventory and elaboration of factual knowledge in the declarative sector of the memory, e.g. all the externally acquired objective knowledge, and even more essentially, tapping into one's own long-term, personal episodic knowledge.

Clarifying the task is gathering knowledge combined with generating, but not executing, viable solutions.

3.3 Description of an object's essence in phase 2: *Core design idea*

Access is granted to an experiential object by defining its essence in the second phase of the procedure planning, *core design idea*. The question "What is…?" is answered by a verbal definition of an object's essence. The definition contains the connotative description of the object to be designed in the highly compressed form of a general thought or schema. These verbalisations mark the first fixed point in the design process. This point contains the determined goal as an anticipated result and is simultaneously the guiding principle for the design process. This determined goal is naturally subjective, individual and private. It gains objectivity with properties of correctness and through the fact that object properties not only differentiate; they can be identical or similar. Based on this subjectivity, *core design ideas* represent coded knowledge and due to their highly compressed form, can only be decoded within the context of the task and of the object.

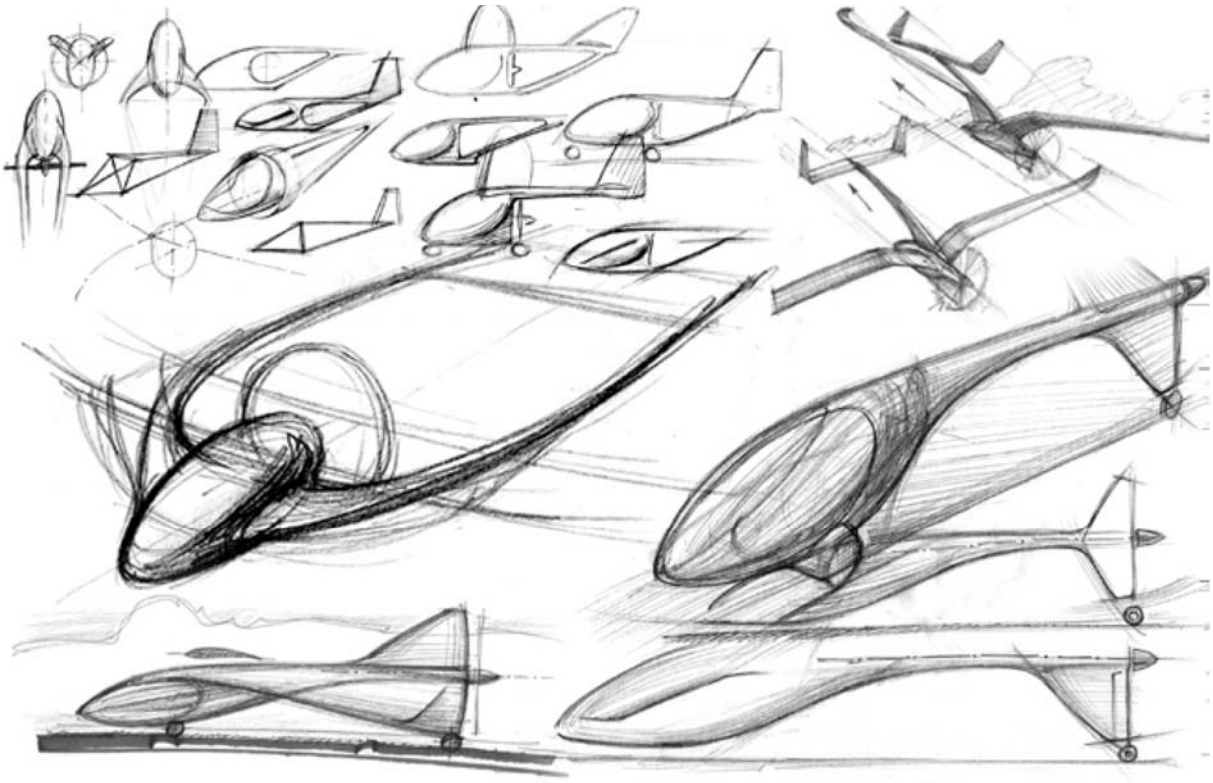

Figure 5: Development example ultra lightweight aircraft: core design idea

A criterion for a *core design idea* and an indicator of its relevance is that it can be externalised (in the sense of object design) and can serve as a launch pad for a fluid design process. The expression, fluid design process, can be used to describe flowing design action, i.e. in the case of a successive and related series of drawings. This can be seen as a sign of an undisturbed regulatory processing of inner operations (see Figure 5).

Both stages *clarify the task* and *core design idea* are characterized by the high amount of internal procedures, which might lead to the term *invisible design process*.

3.4 Problem solving in phase 3: *Hypothetical design proposal*

The content of the phase *hypothetical design proposal* is "presuming by intending" ([13], [15]) the final design by trial in one of the visualising forms belonging to object designing. The designer generates and verifies, in the form of a product hypothesis, the possibility of a synthesis between the *core design idea's* correctness and its appeal. It is here that the procedure planning for the design process differs significantly from the engineering design methodology. The complete design proposal in engineering design methods finds itself at the very end of the development process, resulting from all previous phases. The model of an integrated product development assumes that the phase *clarify the task* according to the procedure planning for the design process and the engineering design phase

clarify and define the task take place simultaneously and whose results can be combined. *Core design idea* and *hypothetical design proposal* are additional phases for the technically directed engineering design methodology. However, for the purpose of developing an experiential object, these phases are the most important, as it is exactly during these phases that decisions regarding *experiencing* are made.

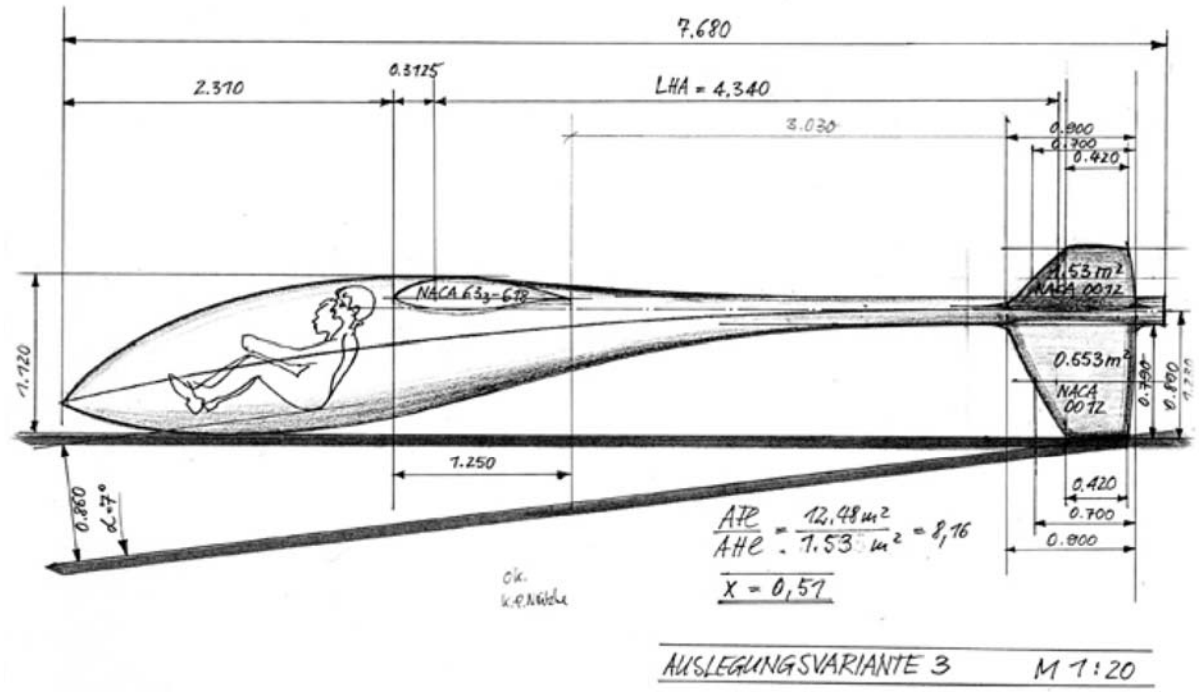

Figure 6: Development example ultra lightweight aircraft: Hypothetical design proposal

3.5 Further course of action

The further course of product development according to Figure 3 is the direct correlation between both methodologies. These phases occur temporally and thematically similarly and correspond to familiar engineering methods, see Figures 7-9.

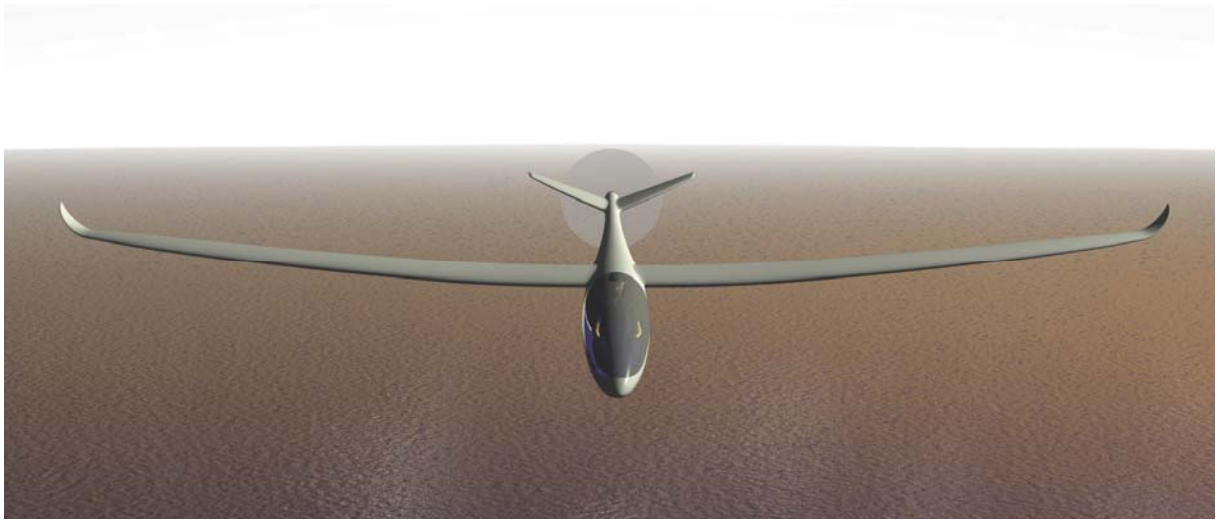

Figure 7: Development example ultra lightweight aircraft: Design proposal (rendered image)

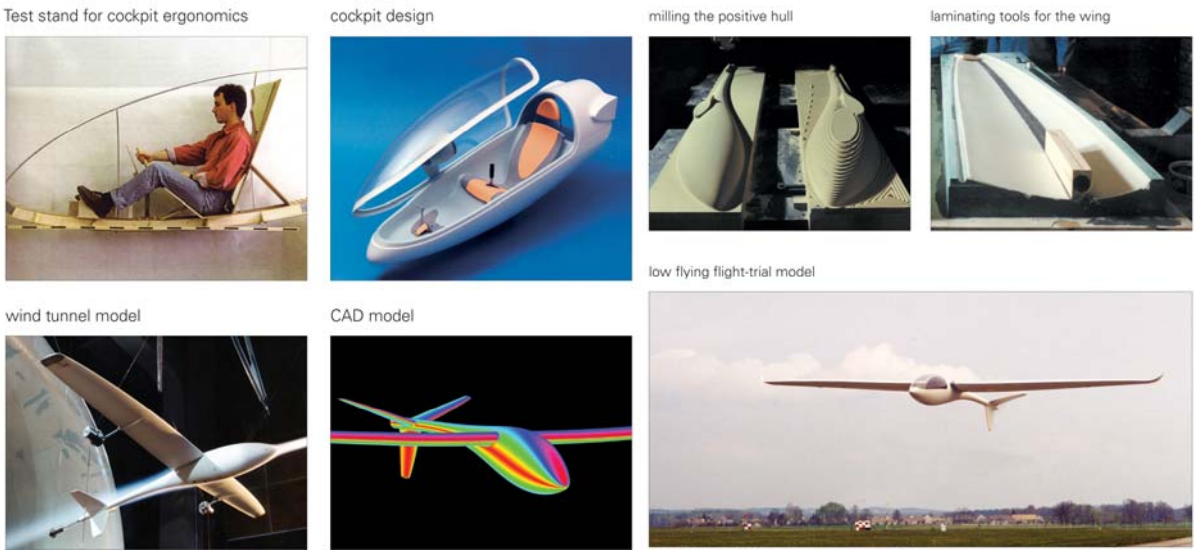

Figure 8: Development example ultra lightweight aircraft: Division into and work on sub-tasks
Figure 9: Development example ultra lightweight aircraft: Further realisation (flight trials)

4 CRITICAL POINTS AND OVERCOMING THEM

With regard to procedure planning and its underlying theoretical fundamentals, some critical points needing special attention result from three circumstances:

- Unfamiliar terminology in comparison with engineering language and learned thought patterns, supported by a designer's biography must be made clear
- Sufficient ability and proficiency in the basic methodology of product design must be trained
- The thought processes of novices when solving complex design tasks, which deviate greatly from an action-regulatory view of an ideal and undisturbed process, may lead to conflicts.

It is possible to analyse and interpret existing individual design processes using psychic action regulation as a methodological fundament and as a guiding principle for procedure planning. It can be used to check and correct one's own actions as well as those of students. This kind of support is also available for sub-actions during the design process, in which the action-regulation is modularly divided and treated separately before integration into a larger action. Difficult phases such as *clarify the task* and *core design idea* can be separated into action units and then supported by training, purposeful reflection, etc.,

5 CONCLUSIONS

This model of a procedure planning for the design process describes the design process based on the action regulation theory for the first time. It can be used for both engineering and industrial design processes and projects. This paper addresses a conflict in the German-speaking countries. It might be understood as basis for a common discourse in both fields of design, hoping to get to an ingenuous cooperation.

The four main points of the procedure planning of the design process are:

- regard to the action regulation theory combined with a clear goal orientation,
- integration into design definition focussed on *experiencing*,
- a description of the design action as the basic activity,
- the design process running mutually internally/externally and the use of objective and subjective evaluation criteria combined to an aesthetic judgement.

Current and future research will deal with further theoretical and empirical work about the single phases of the procedure planning of the design process and supporting methods, whereby the focus lies on the first three phases *clarify the task, core design idea* and *hypothetical design proposal*.

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Contact:

Johannes Uhlmann
Technische Universität Dresden
Faculty of Mechanical Engineering
Industrial Design Chair
01062 Dresden
Germany
Phone +49-351-463-35752 (German only)
Fax +49-351-463-35753
tdesign@rcs.urz.tu-dresden.de (German only)
www.tu-dresden.de/design

Jens Krzywinski
Technische Universität Dresden
Faculty of Mechanical Engineering
Industrial Design Chair
01062 Dresden
Germany
Phone +49-351-463-35750
Fax +49-351-463-35753
jens.krzywinski@tu-dresden.de
www.tu-dresden.de/design