Example on “Usage of Free Sketches in MBSE”

“Raising the applicability of Model-Based Systems Engineering for Mechanical Engineers”

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This publication is made to support the conference paper “Usage of Free Sketches in MBSE”, which was submitted at the First IEEE International Symposium on Systems Engineering (IEEE ISSE; Rome, September 29-30 2015) by MOESER. ALBERS and KÜMPEL. In the IEEE ISSE paper the authors define function-embodiment-synthesis (FES) and free sketches. Also the state of research concerning FES, free sketches and model-based systems engineering (MBSE) is given. A new approach is presented on how free sketches can be used to support a model-based FES. Finally the contribution of the new approach is highlighted and an outlook is given.

In the publication at hand the following example is derived step by step and shows how the new approach can be applied.

I. INTRODUCTION

The Paper submitted at the First IEEE ISSE (see above) is introduced with the following abstract and keywords:

“A major cause for a lack in acceptance of today’s interdisciplinary modeling approaches is the immense difference in abstraction between engineers’ mental models and the available systems modeling languages [1]. Especially mechanical engineers, who use graphical representations like sketches and 3D CAD models, struggle with so called “graphical modeling languages” such as SysML [1][2]. These models represented by two-dimensional diagrams made out of boxes and lines, are not able to display real embodiment aspects and thus do not match with (mechanical) engineers mental models of systems [1].
This paper presents an approach to integrate free sketches into the formal models used in Model-Based Systems Engineering (MBSE). Free sketches are defined as illustrations of technical content. A detailed definition of free sketches and further explanation is given.
Thus this paper contributes to an “Advanced Systems Engineering”, in which a human-centered and model-based approach is targeted [1]. The presented approach supports engineers during function embodiment synthesis by implementing knowledge management aspects.

Keywords—Systems engineering and theory; Modeling; Graphical Models; System analysis and design; Metamodeling” [IEEE ISSE submission by MOESER et al.]

In the IEEE ISSE submission MOESER et al. explain a new approach in relation to the state of research. Model elements are introduced and their application within function-embodiment-synthesis (FES) is introduced. The publication at hand gives a vivid example, because due to restrictions on the number of pages none was given in the IEE ISSE submission.

II. EXAMPLE “LEVER”

A simple lever is used in order to show how the new model elements (see IEEE ISSE submission) are applied. The types and names of the model elements (instances) are given like this: {«ElementType» ElementName}

At the beginning of the function-embodiment-synthesis (FES) the engineer is faced with the challenge to design an embodiment of a system to fulfill certain targeted functions. In the given example only one function is considered: One of the use cases of the system is to move heavy objects, hence the system has to be able to amplify force: {«Function» AmplifyForce} (see Fig. 1). Furthermore a requirement is given, stating that the ratio between output and input force has to be three (see Fig. 1).

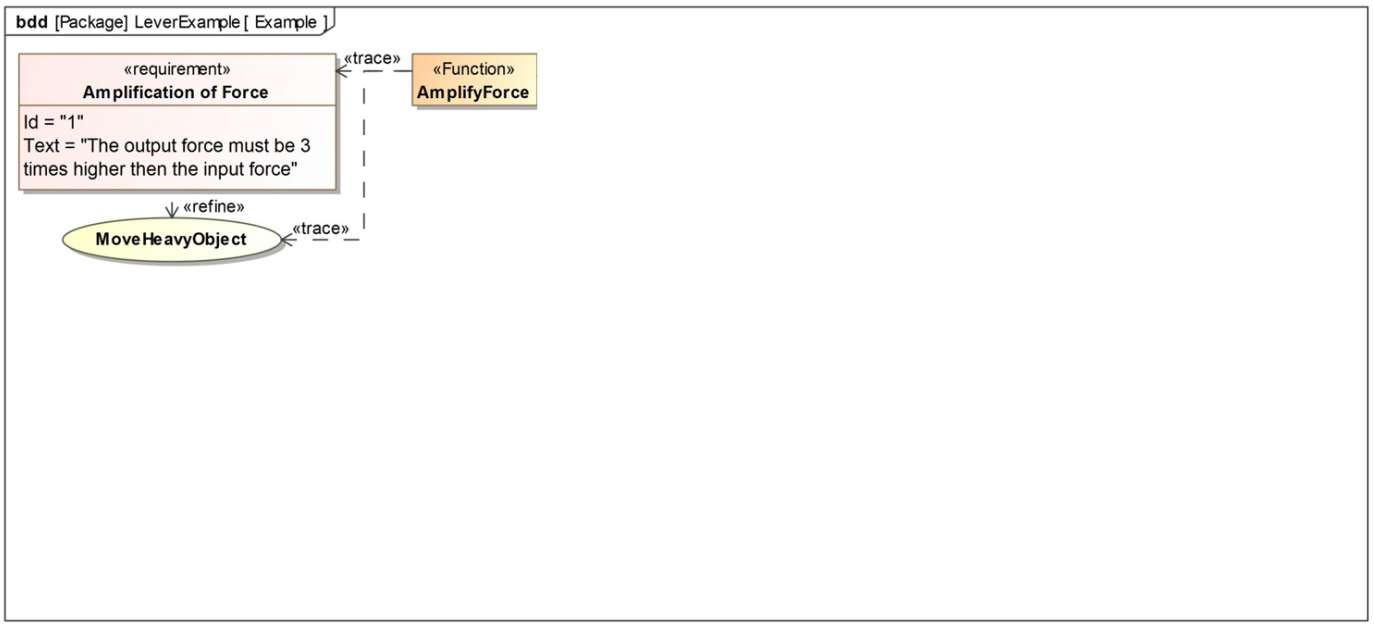

Fig. 1. State 1 of the model: At the beginning of FES a {«Function» AmplifyForce} and further information is given

Next, the engineer is looking for principle solutions. Among others the lever is found:{«PrincipleSolution» Lever}. Since this principle solution was selected for further development, a copy of the model element is created: {«ConceptElement» LeverMechanism}. This has to be done, in order to save the state of the model element {«PrincipleSolution» Lever} in its current state (compare IEEE ISSE submission). Fig. 2 depicts the model with the principle solution and the concept element. Generating the «trace»-link between {«PrincipleSolution» Lever} and {«ConceptElement» LeverMechanism} is subject to tool automation (compare Fig. 2).

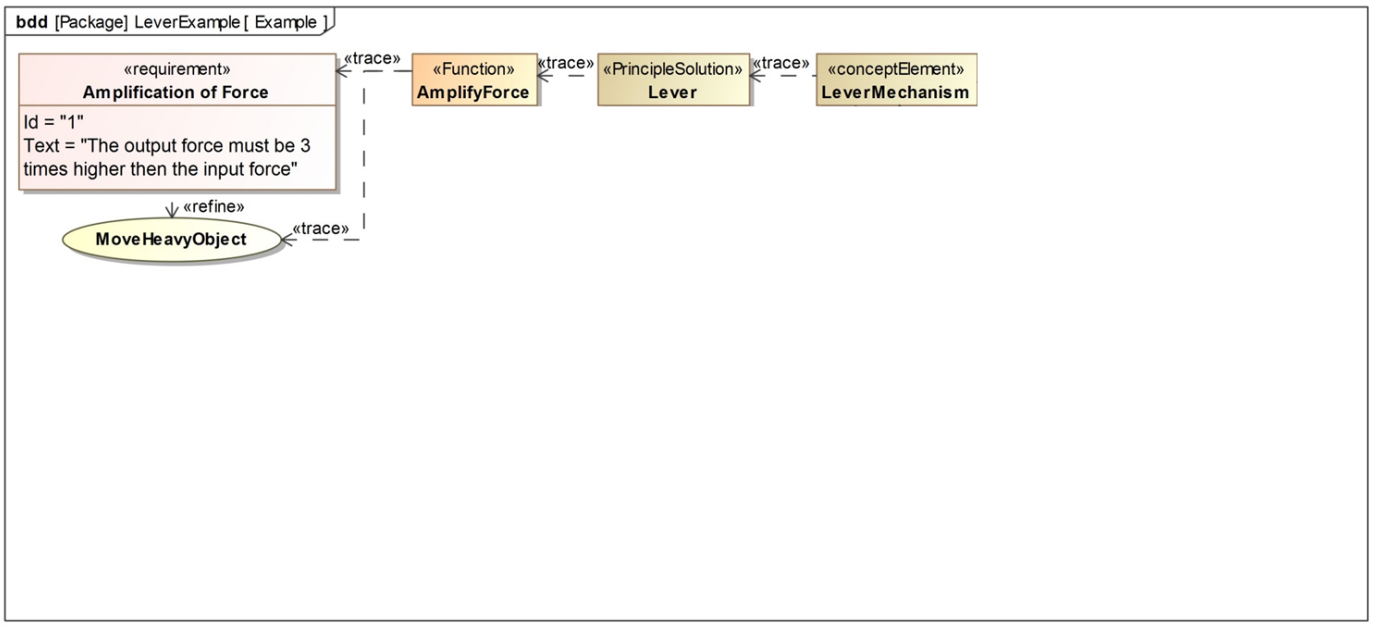

Fig. 2. State 2 of the model: A principle solution was found and selected for further development (thus the concept element was automatically generated)

While concept elements are under development, free sketches are used to stimulate creativity and record fleeting ideas. Such a free sketch is added to the model: {«FreeSketch» First Draft} (see Fig. 3). There is no link modeled between the sketch respectively its content to {«ConceptElement» LeverMechanism} (see Fig. 3).

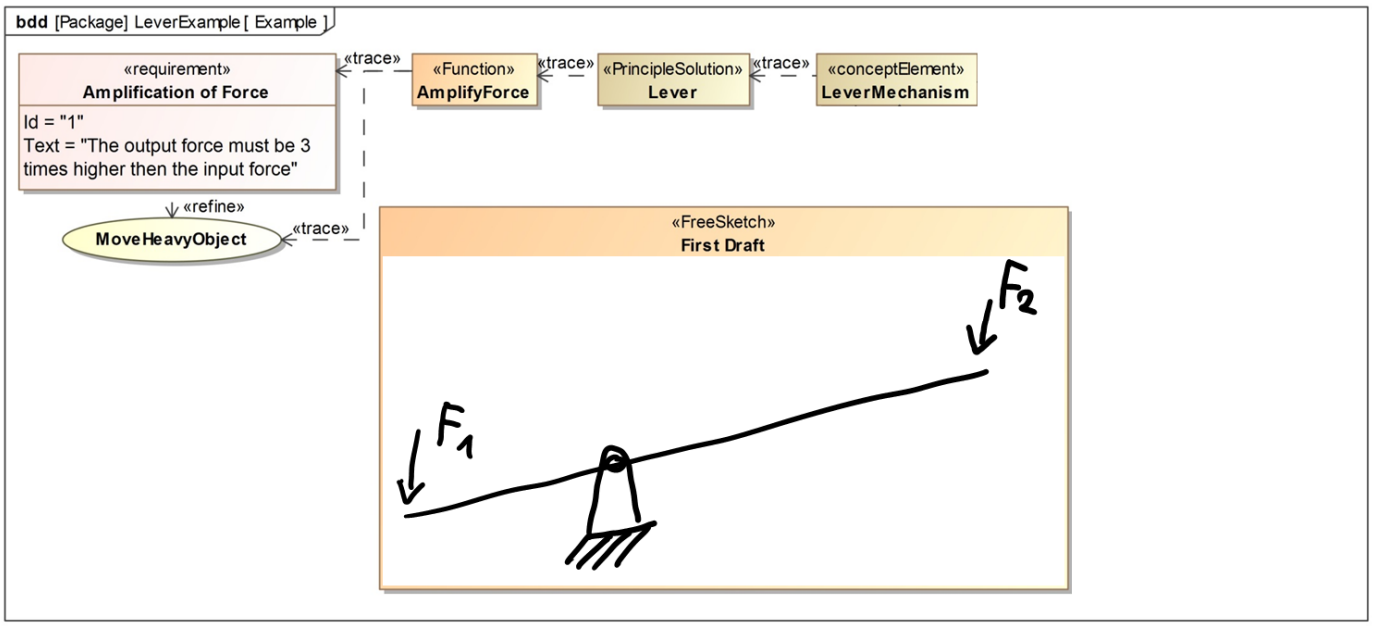

Fig. 3. State 3 of the model: A free sketch was added depicting further details on the {«ConceptElement» LeverMechanism}

In order to add a link, that supports the designer while progressing with FES or in future reviews, a {«SketchSnippet» S1} is added. The Sketch Snippet is a formal model element that can be linked to {«ConceptElement» LeverMechanism} and is visualized by content of {«FreeSketch» First Draft} (see Fig. 4). Thus it links formal model elements and non formal content of the free sketch.

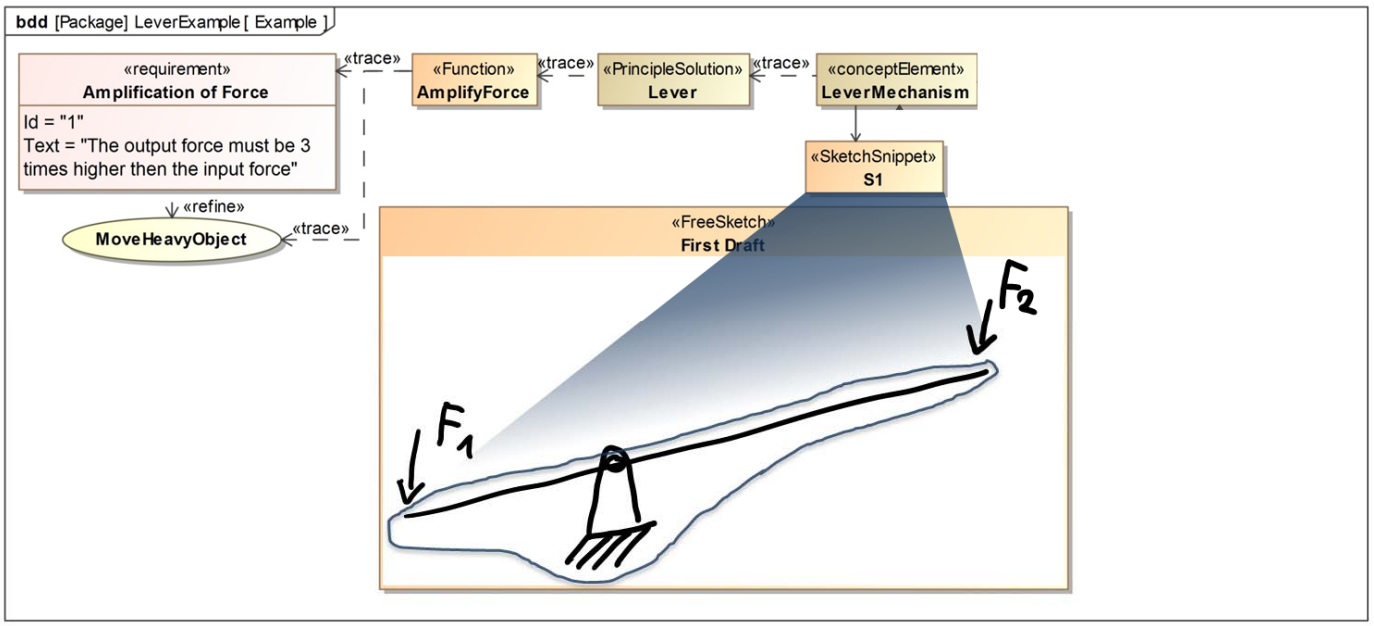

Fig. 4. State 4 of the model: {«SketchSnippet» S1} is introduced

The next step is to explicate the engineer’s knowledge, which was gained while sketching. In the given example three components can be named: {«Component» LeverBar}, {«Component» Bearing} and {«Component» BearingBlock}. All of three are linked to visualizations in {«FreeSketch» First Draft} by using sketch snippets: {«SketchSnippet» S2}, {«SketchSnippet» S3} and {«SketchSnippet» S4} (see Fig. 5)

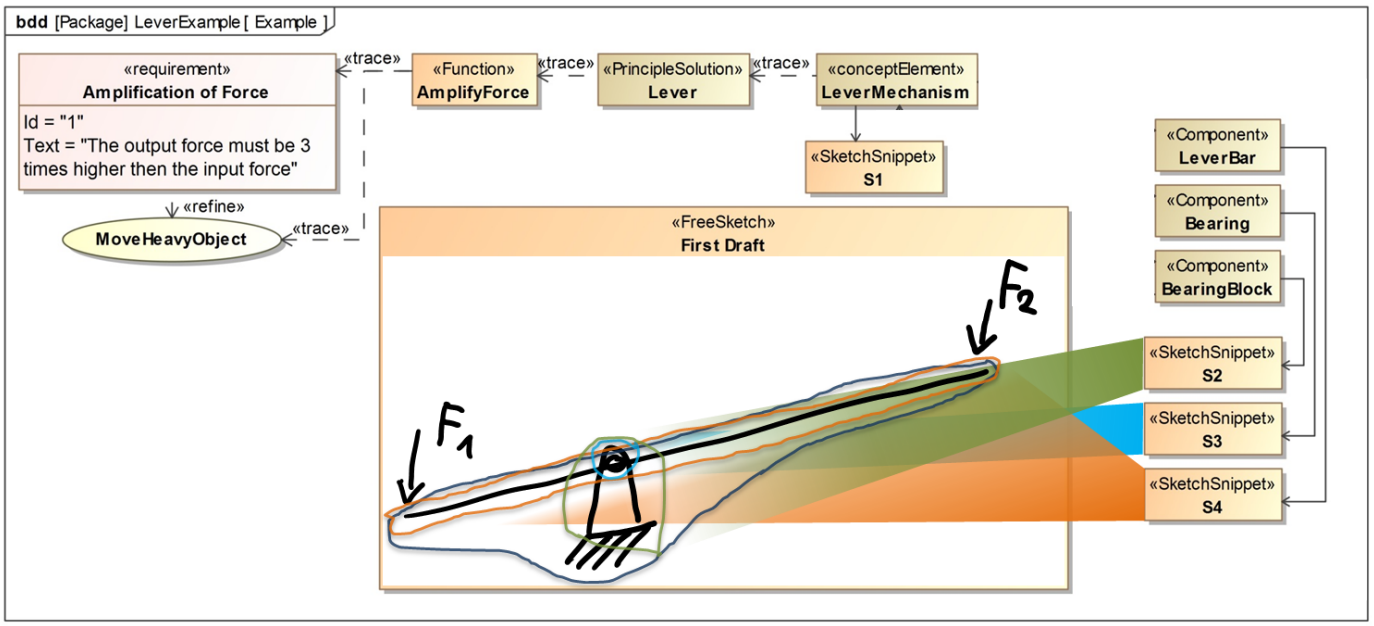

Fig. 5. State 5 of the model: Components lever bar, bearing and bearing block are added; sketch snippets link the model elements to the content of the free sketch

A continuous traceability chain is achieved by linking concept elements and their embodying components. In the future a computer tool will suggest and generate these links by observing overlaps of the sketch snippets depicting concept elements and components. In this example the engineer decided to agree to the suggestions made by the tool as shown in Fig. 6 by the «trace»-links between the three components and the concept element (see Fig. 6).

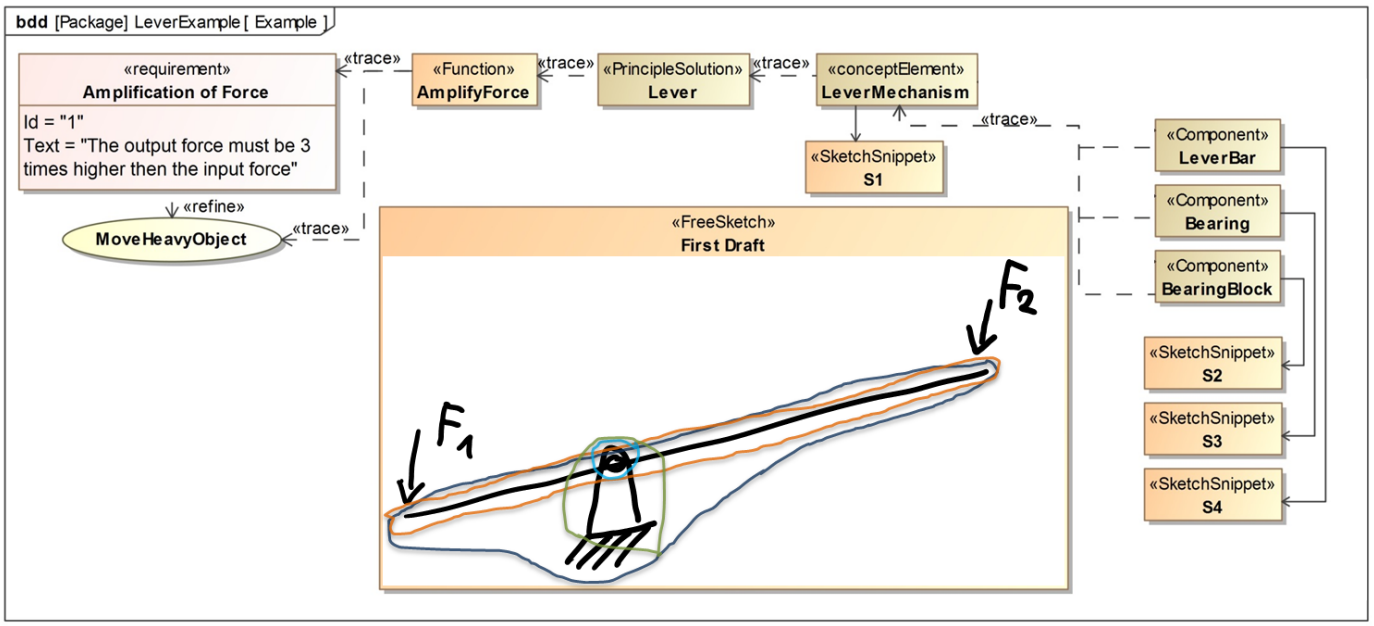

Fig. 6. State 6 of the model: Suggested «trace»-links are added

During further detailing work concept elements and components can be modeled in hierarchical structures. Exemplarily Fig. 7 shows this by introducing a new component (in this example an assembly is used): {«Component» LeverAssembly}. The hierarchy is modeled using composition links (see Fig. 7). The {«Component» LeverAssembly} can also be found in {«FreeSketch» First Draft}. Thus {«SketchSnippet» S5} is introduced as well to link {«Component» LeverAssembly} to the content of the free sketch in question (see Fig. 7). Additionally a «trace»-link interconnects it to {«ConceptElement» LeverMechanism}. (see Fig. 7).

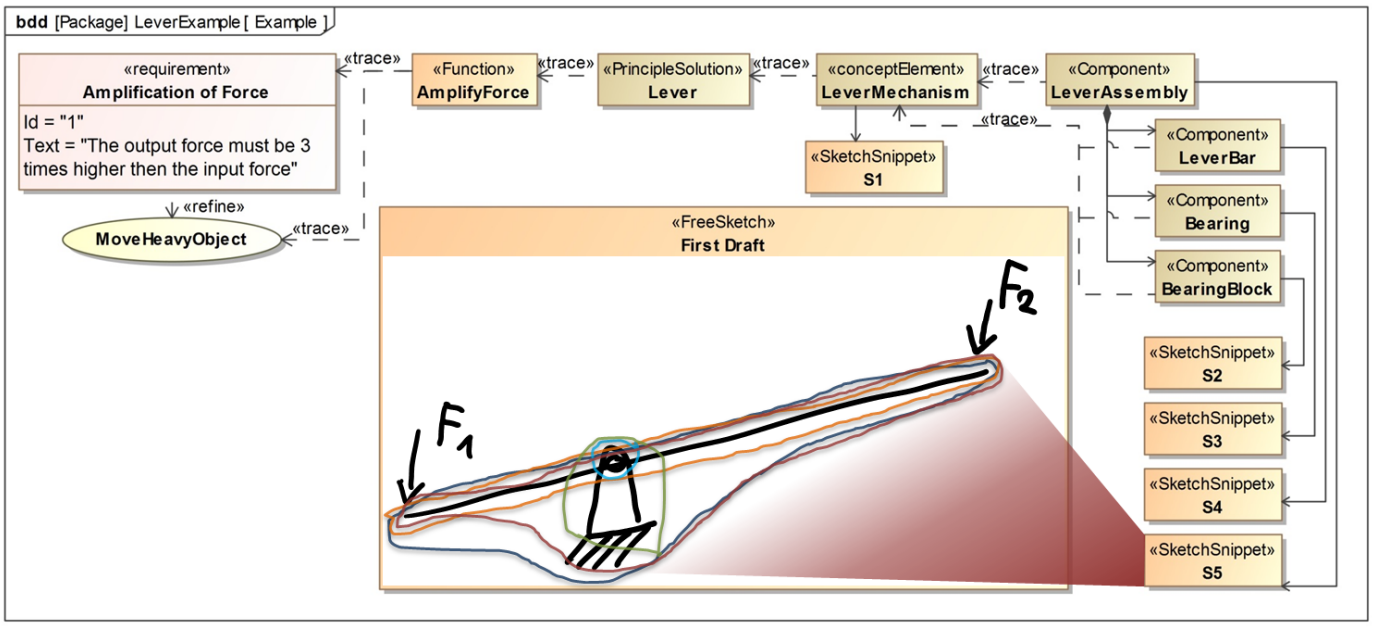

Fig. 7. State 7 of the model: {«Component» LeverAssembly} is added and linked by {«SketchSnippet» S5} to the visual content and linked by the «trace»-link to {«ConceptElement» LeverMechanism}

In Fig. 8 a diagram including all model elements as introduced above is shown. Please note that the colored areas are no model elements. They are introduced to highlight the links between formal model elements and the non formal contents of the free sketch.

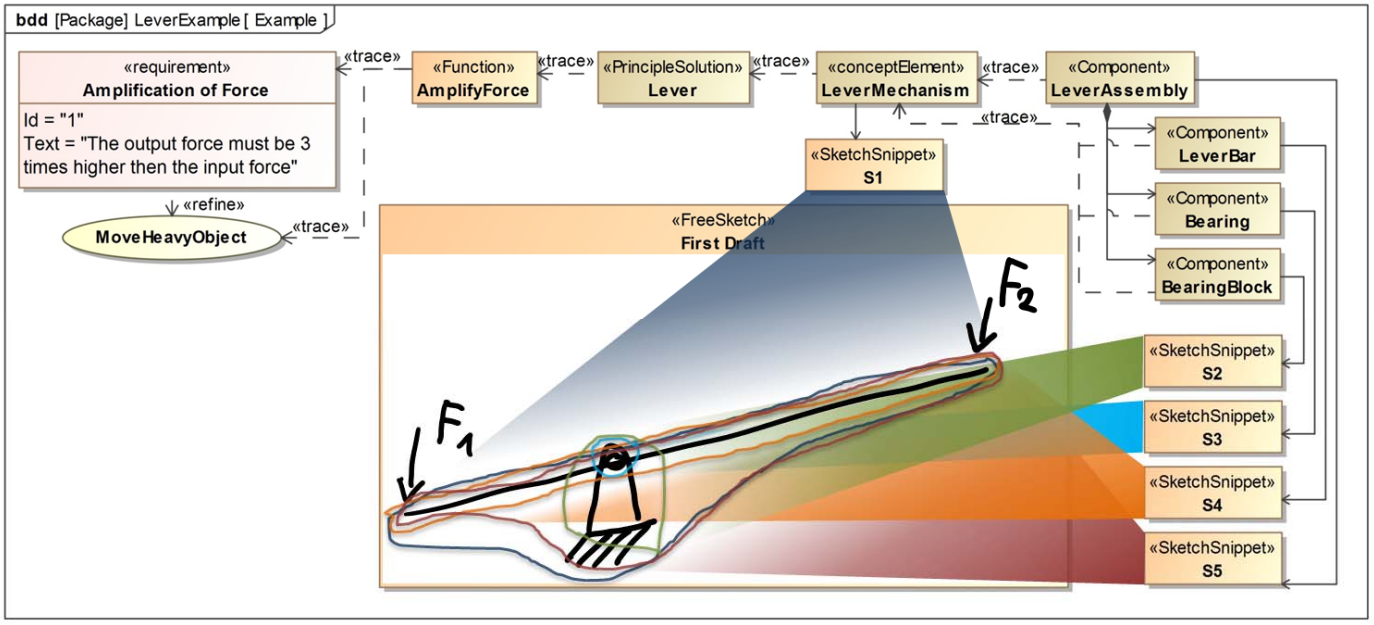

Fig. 8. Model including all of the introduced elements

Further information can be added to the model. For example a {«Parameter» LeverageRatio = 3} can be added to {«Component» LeverBar}. Furthermore a {«constraint» Concentricity} can be added to certain aspects of the embodiment (here: «working surface»s) of {«Component» LeverBar}, {«Component» Bearing} and {«Component» BearingBlock} where the concentricity is needed to mount the bearing. All of the aforementioned aspects can be shown in free sketches, so that all of the model elements can be linked to visual content by using sketch snippets.

III. Additional Notes

Due to simplifications only a very simple traceability chain is shown. In general several sketches (number free of choice) can be used to depict all relevant information concerning the model elements. Furthermore in most cases a component contributes to more than one concept element and thus contributes to more than one function. The approach is scalable, so that systems with an arbitrary number of functions and degree of complexity can be modeled.

More extensive examples will be given in future publications. Examples derived from industry projects will be included as well.