SYSTEMATIC APPROACH TO ENGINEERING DESIGN

LABORATORIO PROYECTO

MAESTRÍA MICROELECTRÓNICA FI-UBA

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SYSTEMATIC APPROACH

- Strategy for the development of solutions which aims to increase the probability of technical and economic success of product design.
- This is done by creating a dependable approach which allows careful planning and systematic execution so that the whole design task reduces to a logical and comprehensible exercise and also allows recovery from inevitable errors.
- It also allocates a time schedule for the design stages which in turn leads to a predictable project timetable.

- **Would all of this take too much time?**
- These steps will need to be examined at least implicitly as a designer prepares a design.
- It is much better to be systematic about it rather than leave to chance whether or not some aspect of the design has been properly covered.

RESEARCH

- Review existing results and products
- Consider problems and successes associated with existing approaches, costs and marketplace needs

- **Output:** Document with all related results and products, and considerations

PROBLEM DEFINITION

- Recognize the need.
  - A need statement defines current unsatisfactory situation.
- Define the goal
  - brief, general and ideal statement.
- Define objectives
  - Quantifiable expectations of performance of design
- Define constraints
  - Requirements that the design must satisfy

- **Output:** Specification document

Definition of Specification: set of documented requirements to be satisfied by a material, design, product, or service.

PROBLEM DEFINITION

- Example:
  - **Need statement**:
    - Current test procedures for the ZZZ are too time intensive
  - **Goal**: How are we going to address the need
    - To design an improved test fixture for the ZZZ
  - **Objective:**
    - Design a fixture that allows loading and unloading of items in less than 5 seconds, and which automatically sequences through the testing conditions
  - **Constraints**: Define permissible range of design and performance parameters
    - Dimensions cannot be modified
    - Test requires 110VAC power for the product

PLANNING

- Schedule activities
  - Gantt chart: what tasks and in what order?
- Cost of activities
  - Personnel time
  - Budget constraints

CONCEPTUAL DESIGN

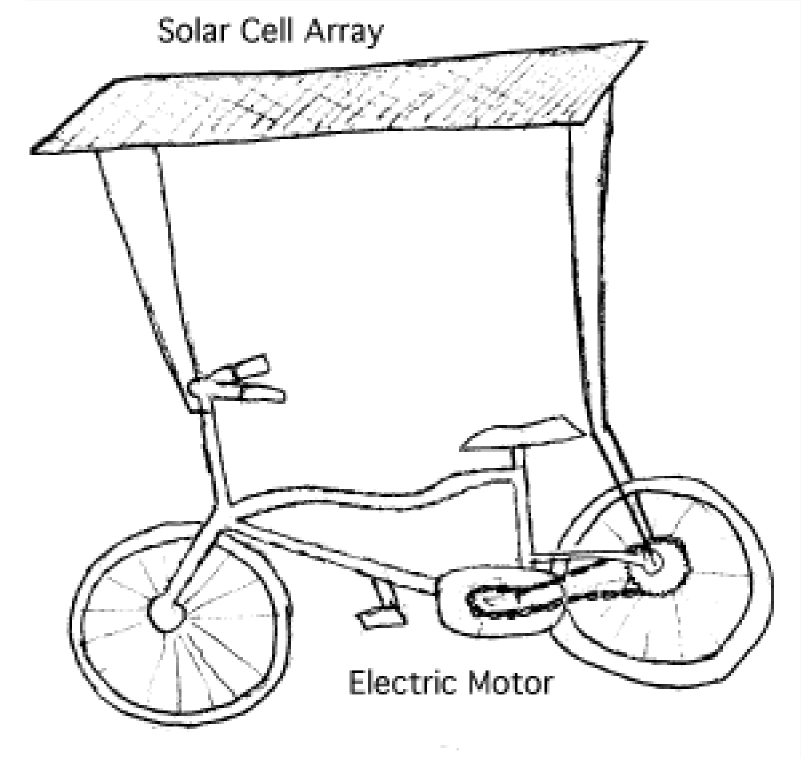
- Abstract the task
- Establish functional **structures**
- Search for solution **principles**
- Combine solution principles and produce variants
  - Brainstorm, let imagination fly. Avoid detail and critique.
- Evaluate variants (technically and economically)
  - Come up with a backup alternative
- **Output:** Different concepts and their functional structures

Before the conceptual design stage is started a decision is needed as to whether a **conceptual elaboration is** really **needed** or whether **known solutions** allow the designer to proceed directly to the preliminary and detail design phase.

CONCEPTUAL DESIGN

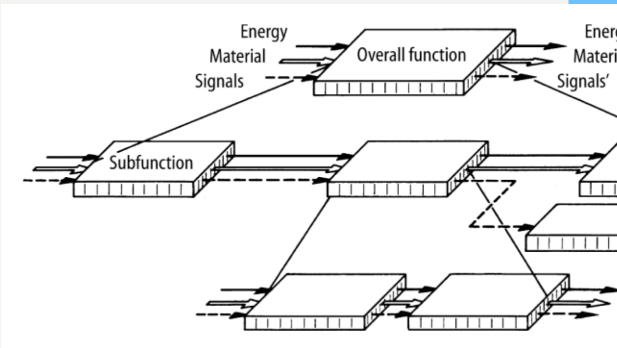
Energy Source	Vehicle Configuration	Drive Mechanism
Solar cells (photovoltaic)	Four wheels	Clutch, gear box, and drive shaft
Human Power	Three wheels	Wheel hub motors
Wind Energy	Two wheels (bicycle)	Chain drive with gears
Gasoline (fossil fuel)	Two wheels (side to side)	
Ethanol		

Wide options



PRELIMINARY DESIGN

- Break down the system into sub-systems and lower level elements
- Allocate the system requirements down to the elements or level desired (so that is a meaningful input for design)
- Synthesis: define combination and structure of components (not final). Several approaches are possible.
- Analysis: evaluate the approaches (modelling, simulation, etc) and their performance and determine the preferred approach
- **Output**: An overall system **configuration** with performance, cost and other requirements



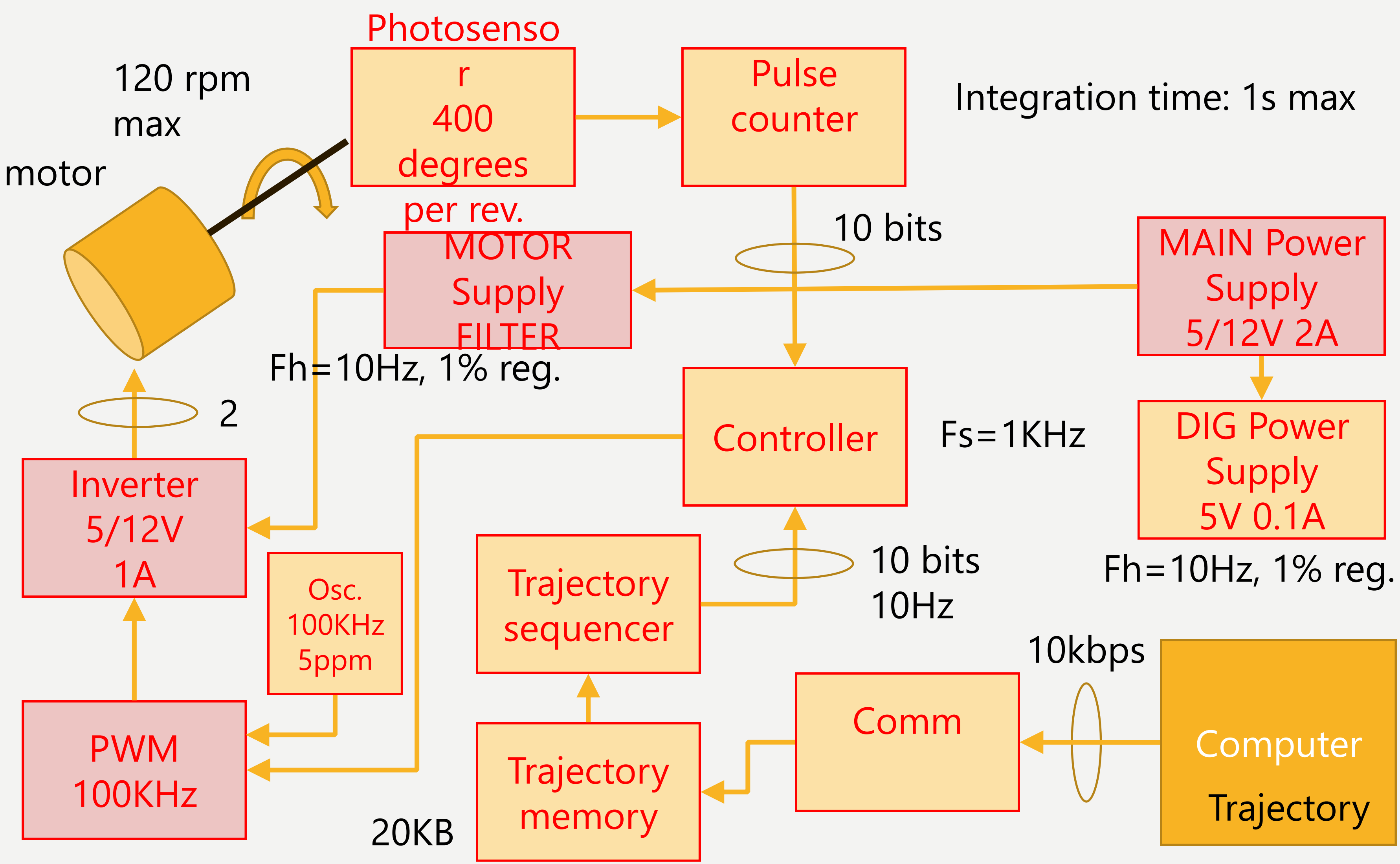
This is the very latest to which assessment of financial viability of the project can be left.

PRELIMINARY DESIGN

- Clear definition of the subsystems and their interfaces
- Electronic systems
  - System Block Diagram, followed by a description of the subsystems, their interfaces and requirements.
- Mechanical
  - 3D mechanical rendering of the system with subassemblies clearly identified. (Exploded View of the system, followed by a description of the subsystems, their interfaces and requirements).
- Software
  - Structural framework of physical components. A hierarchical decomposition of the physical components of the solution, down to the level of individually compiled program units.
  - For every physical component: functional components, interfaces, languages and tools for implementation, diagram with flow of information).

ELECTRICAL

System block diagram

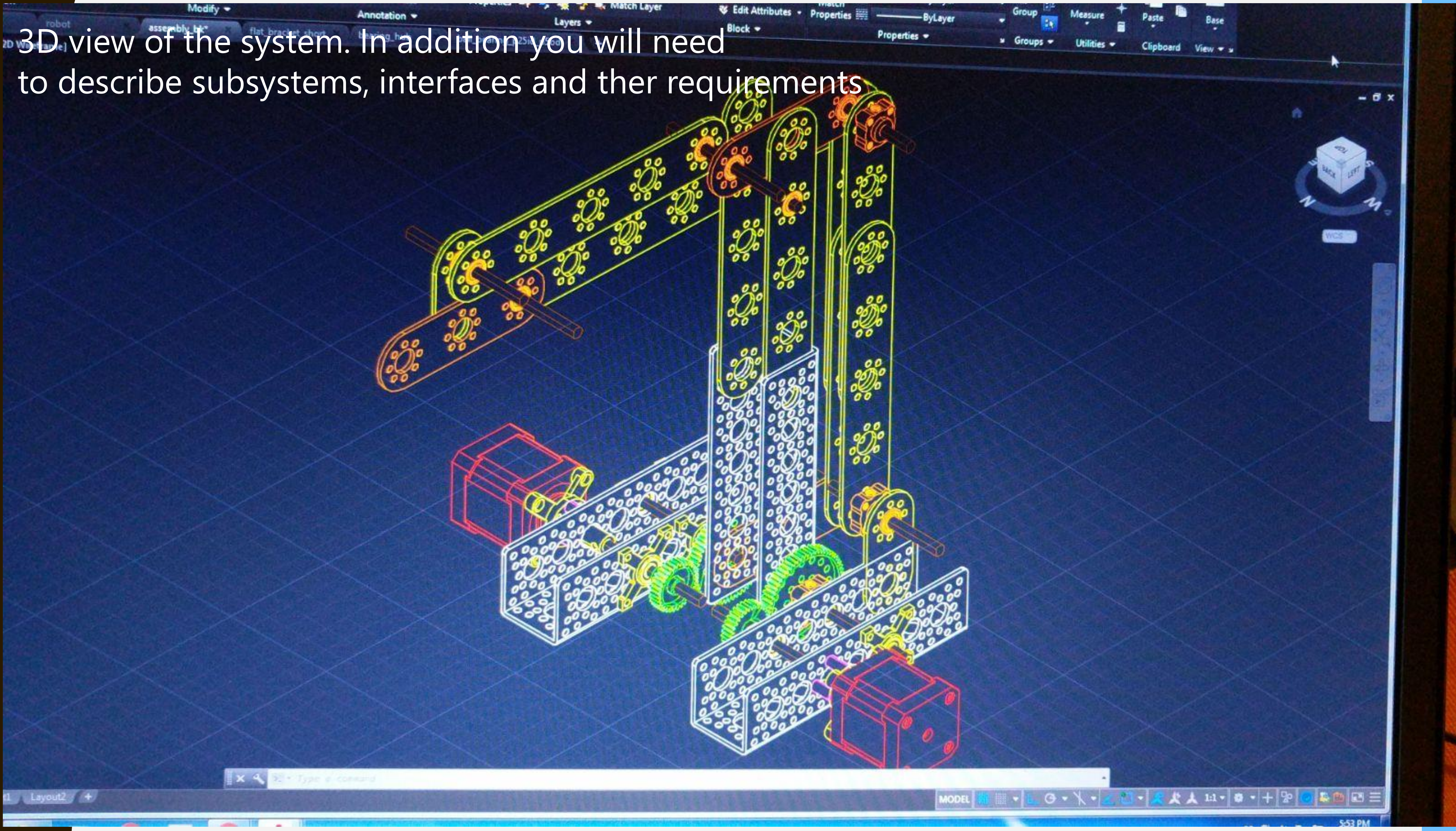


ELECTRICAL

- Next, you specify the **requirements** for each block and interface. For example, for the digital power supply:
- 1) Digital power supply requirements
  - Vi = 7-20V
  - Io = 1 A
  - T = 0 to 125 °C
  - Load regulation: < 100mV
  - Quiescent current: 50mA max
  - Dropout voltage: 2V
  - Output noise: 50uV
  - Output voltage drift: 1 mV / °C

MECHANICAL

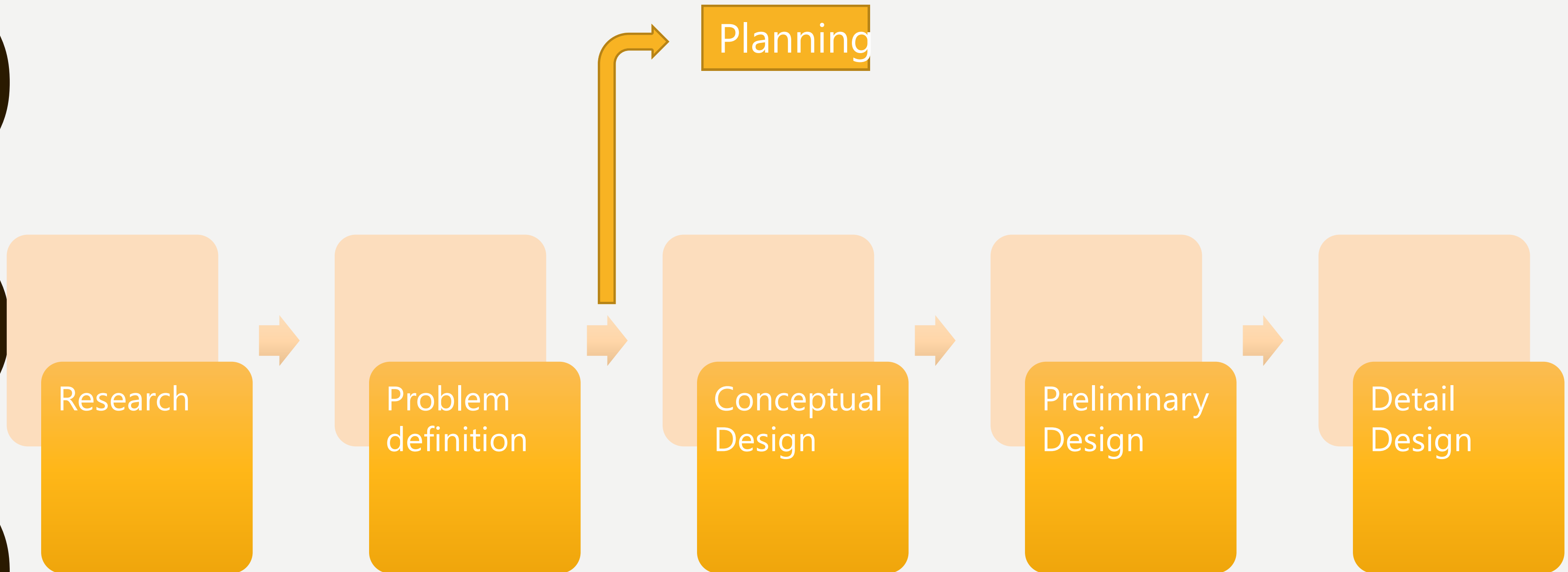
3D view of the system. In addition you will need
to describe subsystems, interfaces and ther requirements



DETAILED DESIGN

- Definition of system elements:
  - Subsystems, units, assemblies, lower-level component parts, software, data, and the elements of logistics support.
- This phase further elaborates each aspect of the project/product by complete description through solid modeling, drawings as well as specifications.
- Preparation of design data
- Physical models of system or major components
- System integration and test
  - Verification that requirements have been met
- **Deliverable:**

DESIGN FLOW


Planning
Research
Problem definition
Conceptual Design
Preliminary Design
Detail Design

- **Would all of this take too much time?**
- These steps will need to be examined at least implicitly as a designer prepares a design.
- It is much better to be systematic about it rather than leave to chance whether or not some aspect of the design has been properly covered.

SCHEDULE

- Gantt Chart
  - Create a list of all tasks
  - Estimate the duration of each task and who's responsible
  - Identify key milestones in the project
  - Think and decide which tasks are independent (or **floating**) and which **depend** on other ones

SCHEDULE

- Gantt Chart example
- Board design
    - Tasks
    - Simulate schematics w/Spice: 10 days - John
    - Draw PCB: 7 days - Charles
    - Fabricate PCB: 10 days - Charles
    - Order components: 4 days - John
    - Assembly PCB: 3 days - Martin
    - Test: 2 days - John
  - Milestones
    - Working Schematic
    - PCB design
    - BoM
  - Think and decide which tasks are independent (or **floating**) and which **depend** on other ones

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GERHARD PAHL AND WOLFGANG BEITZ'S THEORY OF SYSTEMATIC ENGINEERING DESIGN & PRACTICE

1. START OFF WITH PRODUCT PLANNING AND A CLARIFICATION OF THE TASK

- 1.1 Clarify the task and build out the specification and requirements
  - The specification may not be comprehensive and often will require **clarification** and additional information.
  - determine the **clear aims** that the solution needs to achieve.
  - be sure that there will be the requisite commercial motivation and intellectual stimulation to carry the design through to fruition.
  - At the end of this phase the **specification will be fully developed** and **requirements and constraints compiled**.

2. CONCEPTUAL DESIGN PHASE

- Before the conceptual design stage is started a decision is needed as to whether a **conceptual elaboration is** really **needed** or whether **known solutions** allow the designer to proceed directly to the preliminary and detail design phase. If not, then a conceptual design phase needs to be undertaken.

2. CONCEPTUAL DESIGN PHASE

- 2.1 Abstract the task to identify the essential problem
  - Abstracting the task means describing it in the broadest way. This makes clear what the overall function should be. Too narrow a view of the task, or a quick prejudged one, may well lead the designer down a path to a non-optimum solution; one which would ultimately detract from the technical and economic success of the product.

2. CONCEPTUAL DESIGN PHASE

- 2.2 Establish the functional structures
  - This is both an articulation of the boundaries of the solution (what is in and out of the design) and the functional way in which energy, material and signals (information) flow (are processed or converted) from input to output to meet the specification. It involves breaking down the overall function into sub-functions until the sub-function task becomes clear and simple. In essence, the development of functional structures aims to assist in discovering solutions.

2. CONCEPTUAL DESIGN PHASE

- 2.3 Search for solution principles
  - There may be many means and ways in which a solution to a sub-function can be achieved and the designer seeking an optimum technical and economic solution will need to elaborate a wider range of possible solutions in order to be able to assess the comparative merits of each possibility.
  - A successful solution is more likely to spring from the choice of the most appropriate principle than an exaggerated concentration on the finer points.

2. CONCEPTUAL DESIGN PHASE

- 2.4 Combine the solution principles into variants
  - The larger product is built up from smaller solutions proving the sub-functions. As a result there is likely to be a number of product concepts or variants which can be derived in this way.
  - This development of solution options is the strength of the systematic approach.

2. CONCEPTUAL DESIGN PHASE

- 2.5 Evaluation of concept variants using technical and economic criteria
  - The designer needs to first draw up a set of evaluation criteria and then assess the relative merits of a solution using a bottom up approach starting from the sub-functions which make up each concept variant. In this way a comparative technical and economic evaluation can be built up for each concept variant and allows a decision to be made as to which particular solution should be manufactured.
  - An additional purpose of such an evaluation is to select one or two back-up solution which, while not as cost-effective, could nevertheless be deployed in place of the first choice should this turn out to be necessary.

3. EMBODIMENT DESIGN

- In the embodiment design stage, many details will need to be clarified, confirmed or optimised and as this is done it will become more obvious whether the right solution concept has been chosen.
- No embodiment design can hope to correct a poor solution concept.
- The end of the embodiment design is the very latest to which assessment of financial viability of the project can be left.

3. EMBODIMENT DESIGN

- 3.1 Develop a definitive layout and check that the requirements are met
  - For each concept solution variant the designer will need to determine the layout which will end up being the technical product or system and check that function, strength and spatial compatibility requirements are met.

4. CARRY OUT A DETAIL DESIGN

- 4.1 Detail design
  - The exploration of options does not finish with a conceptual solution but extends to the physical realization of the products. Again the principle of systematic design should be applied to make the choice of suitable components, materials, forms and finishes.
- 4.2 Documentation
  - Detail design also includes the production of final design drawings which can be used to manufacture the product. This firms up each possible product concept solution into a potentially manufacturable design. At this stage, a designer can say that they have explored all of the factors which potentially could significantly impact on the design, ending up with one or more potentially manufacturable designs.

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