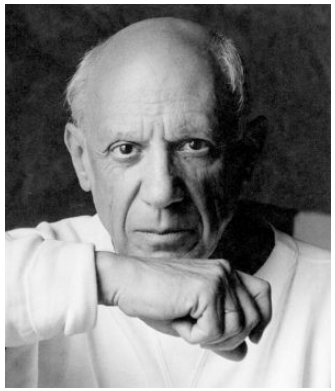
Engineering Design & The Design Process

Cezanne vs Picasso (how does genius emerge)

Paul Cézanne

1839-1906 (aged 67)
Aix-en-Provence, France



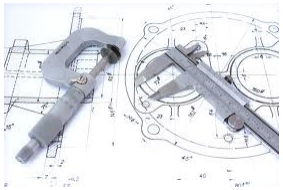
Pablo Picasso

1881-1973 (aged 91)
Málaga, Spain

Card players of Cezanne

Where and when do engineers design?

"Some men see things as they are and say, 'Why?' I dream of things that never were and say, 'Why not?"[1]



- Paraphrasing the late Robert F. Kennedy:
  - Scientists see things as they are and ask, Why?
  - Engineers see things as they could be and ask, Why not?

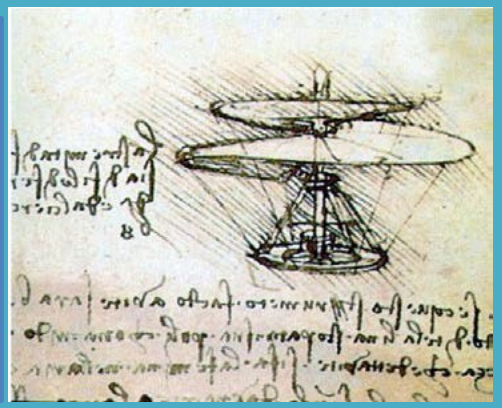
- Essence of new design according to an experienced engineer:
  - Cheaper
  - Faster
  - Better

1-Robert F. Kennedy

From idea to product

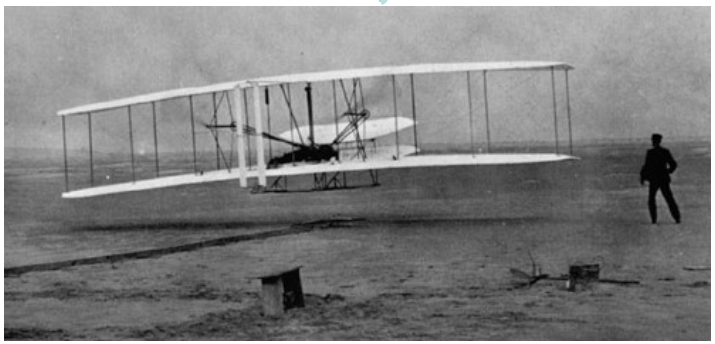
SPECIFICATIONS

Device to be built of wood, reeds and taffeta. "A small model can be made of paper with a spring like metal shaft that after having been released, after having been twisted, causes the screw to spin up into the air."



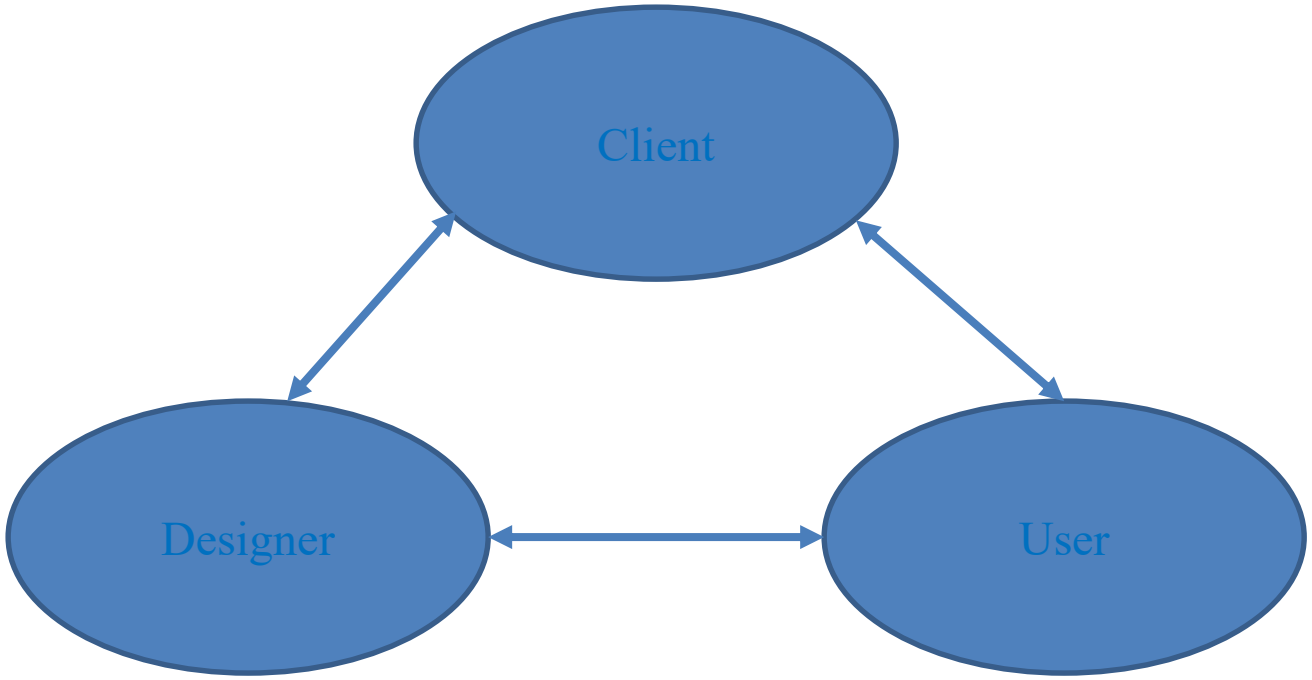
IDEA

PRODUCT



Origin of idea:

Design activities always include at least three stakeholders:



The designer–client–user triangle shows three parties involved in a design effort:
A client, who has objectives that must be realized.
The users of the design, who have their own wishes.
The designer, who must design something that can be built and that satisfies everybody.

Airplane design:

- The nature of the work of designers depends, in part, on whether they are doing:
  - Conceptual design - the stage at which basic questions of form and content for a design are established, including the nature of the goals of the designed item.
  - Detailed design - a stage in the design process after conceptual design (and after preliminary or embodiment design), when specific details particular to the design are resolved.

U.S. Army Corps of Engineers Sacramento District

Courtesy of USFWS

Matt York / Associated Press

© GA161076 / iStockphoto

Wheelchair design:

Image Source / Getty Images

© 26ISO / iStockphoto

© Daniel Korzeniewski / Shutterstock.com

Amos Winter, Daniel Frey, and Global Research Innovation and Technology (GRIT)

Engineering design:

- Engineering design **is the systematic, intelligent generation of specifications for artifacts whose form and function achieve stated objectives and satisfy specified constraints**
  - **Artifacts: human-made objects,**
  - **Form: the shape of the artifact,**
  - **Function: those things the artifact is supposed to do,**
  - **Specifications: descriptions of properties of the object being designed,**
  - **Objectives: attributes of the designed artifact that make it "good",**
  - **Constraints: specifications which the artifact must meet to be acceptable.**

Engineering design:

- Engineering design **is the organized thoughtful development and testing of characteristics of new objects that have a particular configuration or perform some desired function(s) that meets our aims without violating any specified limitations.**
  - **Design is a thoughtful process that can be understood.**
  - **Design can be aided by the use of formal methods.**
  - **Communication is a key issue in successful design.**

Learning and doing engineering design:

- Engineering design problems are challenging because they are usually ill structured and open-ended:
  - Ill structured : their solutions cannot normally be found by applying mathematical formulas or algorithms in a routine or structured way.
  - open-ended: they typically have several acceptable solutions.


© seraficus / iStockphoto

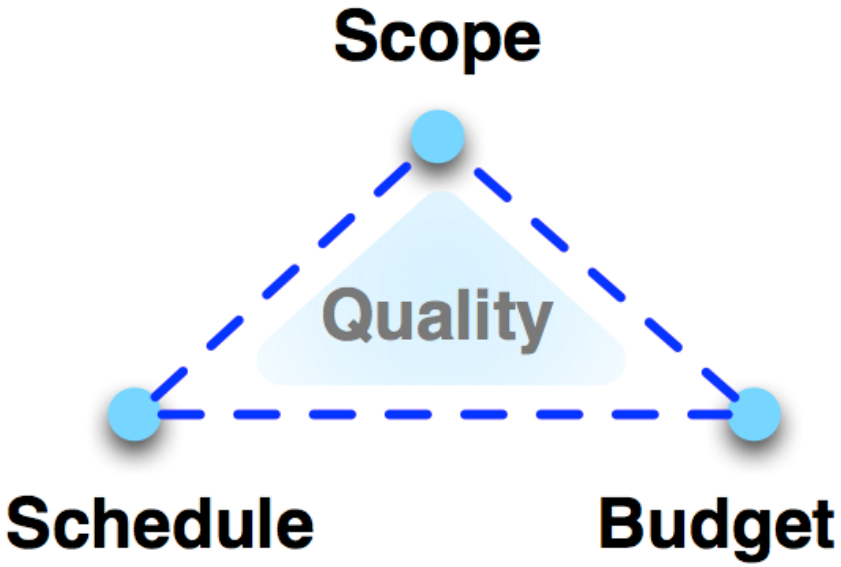

© ZargonDesign / iStockphoto


© Cora Reed / Shutterstock


J. A. Kraulis / Masterfile

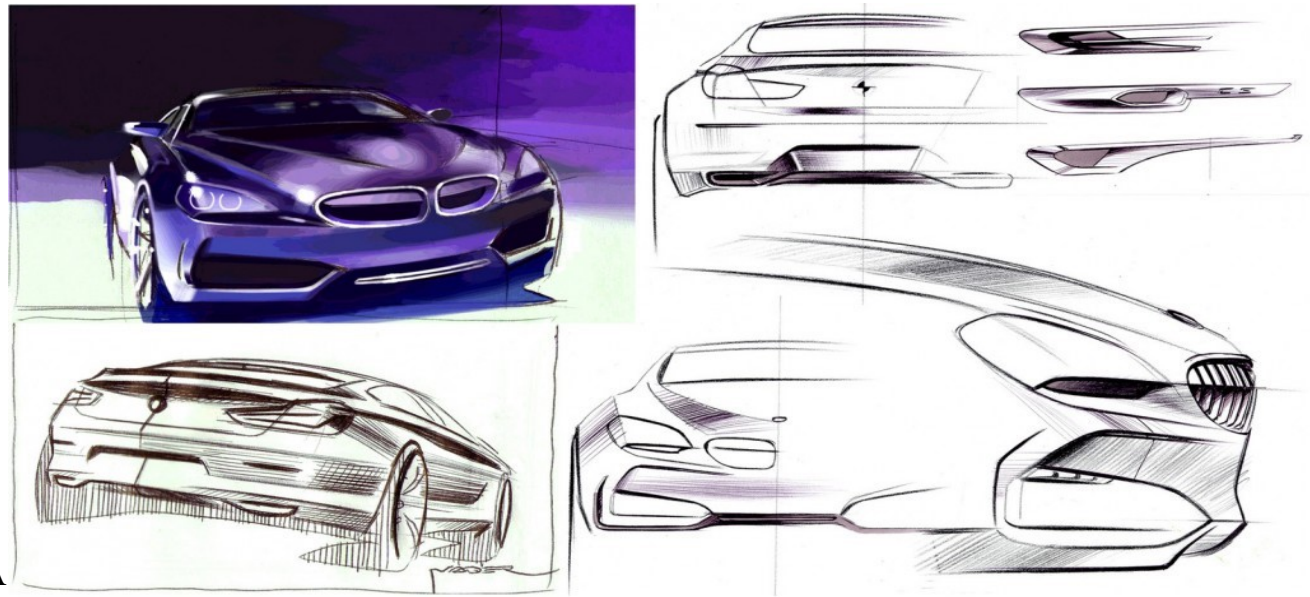
MANAGING ENGINEERING DESIGN PROJECTS:

- To be successful, a design project must track scope, schedule, and spending:
  - Scope : deciding what a project must accomplish to be successful.
  - Schedule : making sure that resources needed to accomplish the project scope are available and used when needed to complete the project by its agreed-upon due date.
  - Budget : ensuring that a design project uses only the resources necessary to complete the project on time.

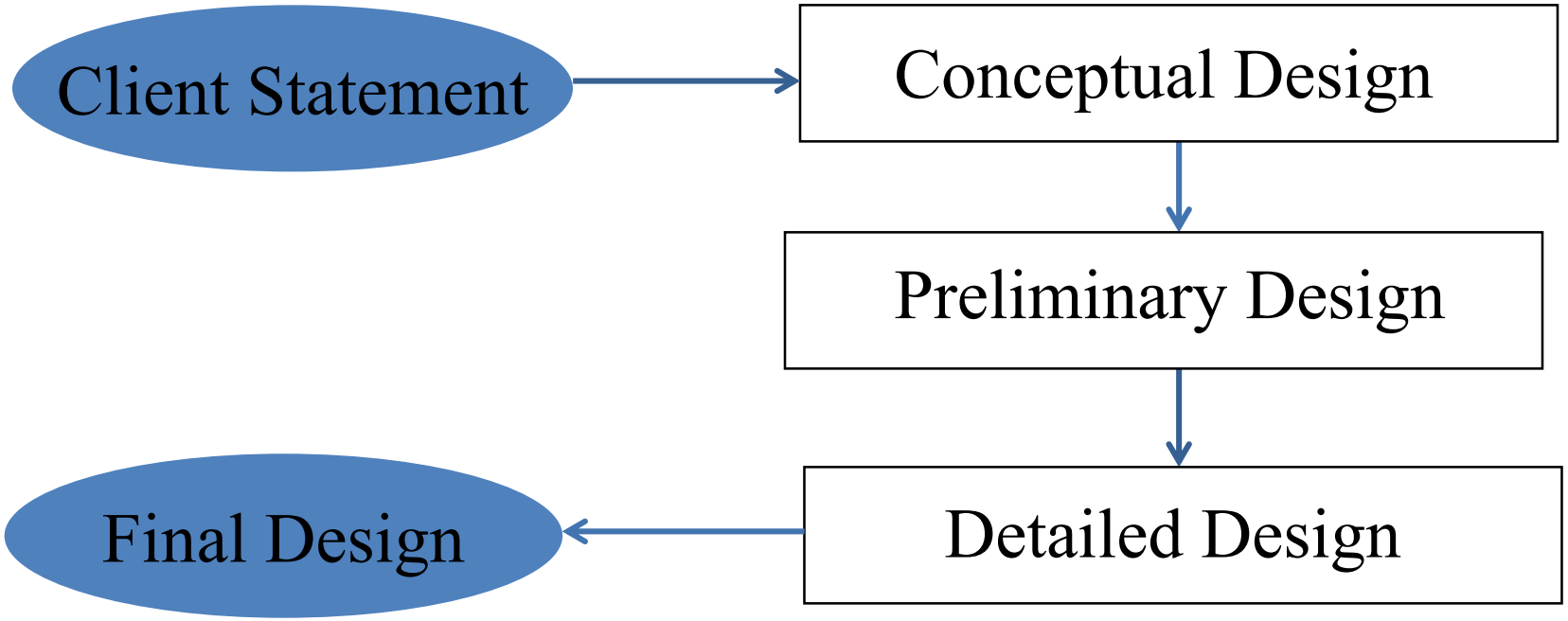


Design and it's process:

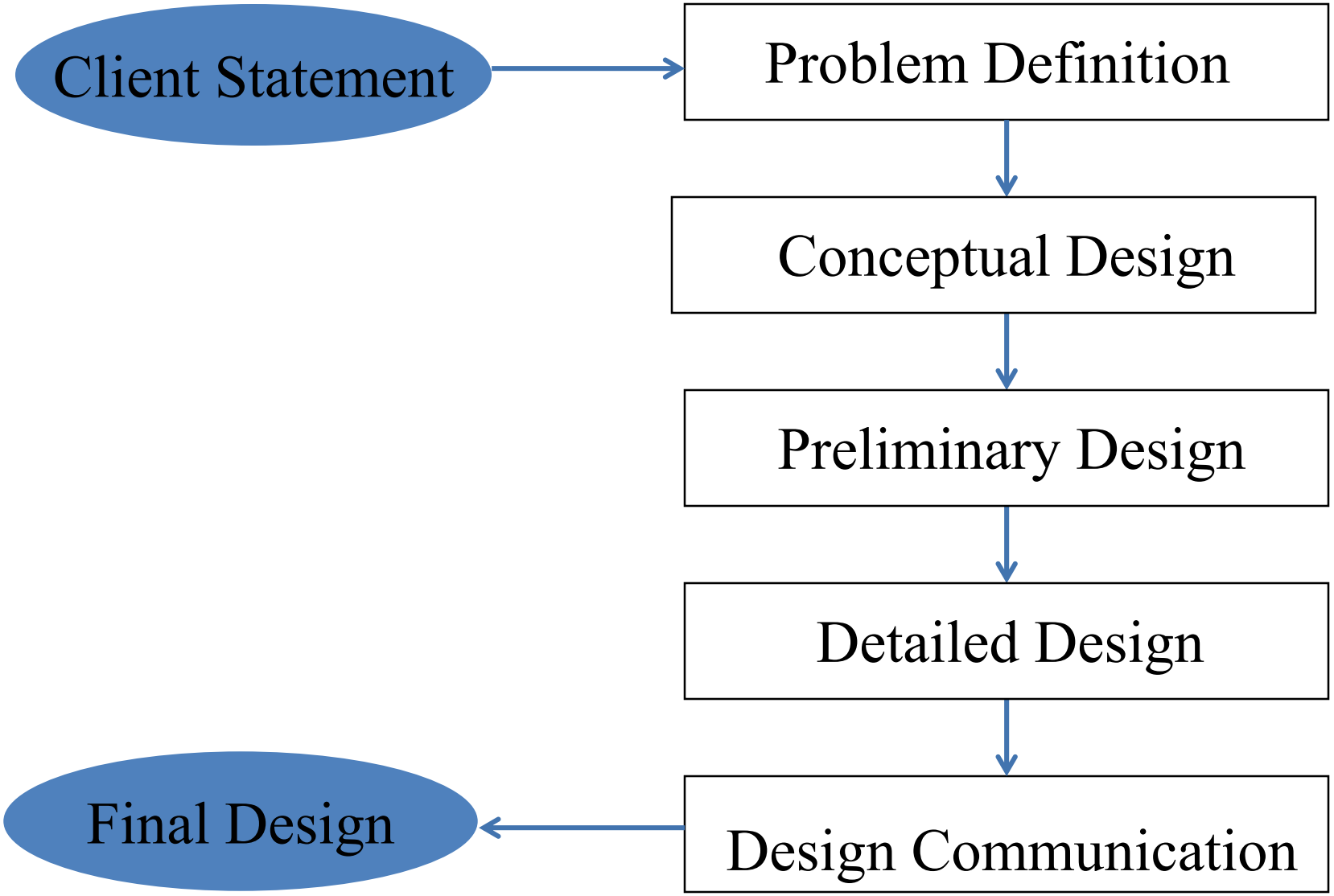
- The word design is often used as a generic term that refers to anything that was made by a conscious human effort.
- Design is also a process that is used to systematically solve problems.
- A design process is a systematic problem-solving strategy, with criteria and constraints, used to develop many possible solutions to solve or satisfy human needs or wants and to narrow down the possible solutions to one final choice.



Three-Stage descriptive model:



Five-Stage descriptive model:



Problem definition:

- Clarify objectives
- Establish user requirements
- Identify constraints
- Establish functions

- **Input:** *original problem statement*

- **Tasks:**
  - *revise client's problem statement*
  - *clarify objectives*
  - *identify constraints*
  - *establish principal functions*

- **Outputs:**
  - *customer requirements:*
  - *revised problem statement*
  - *initial list of final objectives*
  - *initial list of constraints*
  - *initial list of principal functions*

Conceptual design:

In this stage of the design process the customer requirements are translated into engineering specifications to generate concepts or schemes of design alternatives or feasible (i.e., acceptable) designs.

- **Input :**
  - *customer requirements*
  - *revised problem statement*
  - *initial list of final objectives*
  - *initial list of constraints*
  - *initial list of principal functions*
- **Tasks:**
  - *establish functional specifications*
  - *establish means for functions*
  - *write limits or boundaries of constraints*
  - *develop metrics for objectives*
  - *generate design alternatives*
  - *refine and apply metrics to design alternatives*
  - *estimate design alternatives' major attributes*
  - *choose a design concept*
- Outputs: *a chosen design analysis, test, and evaluation results for chosen design*

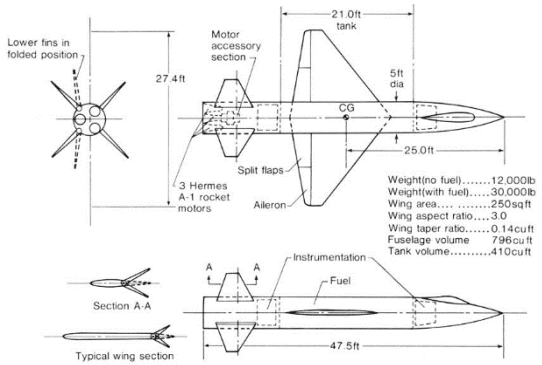
Preliminary design:

- In the preliminary design phase we identify and preliminarily size/estimate the principal attributes of the chosen design concept or scheme.

- Input : *a chosen design specifications*

- **Tasks:** *model and analyze chosen design*; *test and evaluate chosen design*

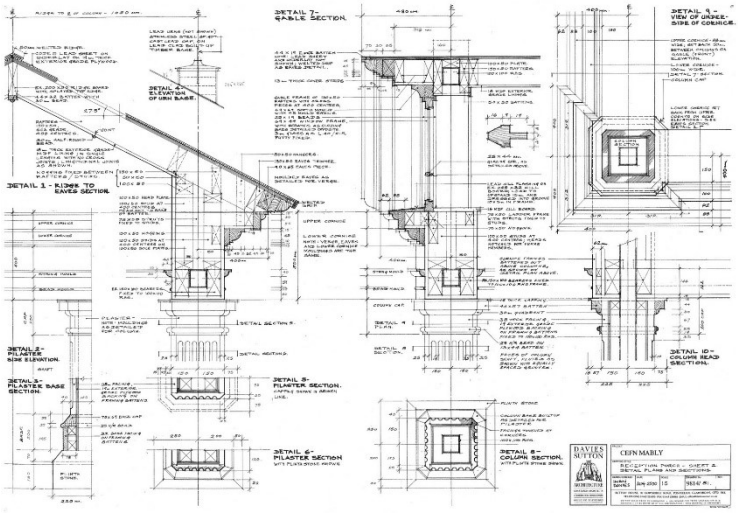
- Outputs: *analysis, testing, evaluation of chosen design*



Detailed design:

During detailed design we refine and optimize the final design and assign and fix the design details.

- Input : *the analyzed, tested, evaluated design*
- **Tasks:** $\begin{cases} refine, optimize\ the\ chosen\ design \\ assign\ and\ specify\ the\ design\ details \end{cases}$
- Outputs: *proposed design and design details*



Design communication:

During the design communication phase we document the fabrication specifications and their justification.

- Input : *proposed design and design details*

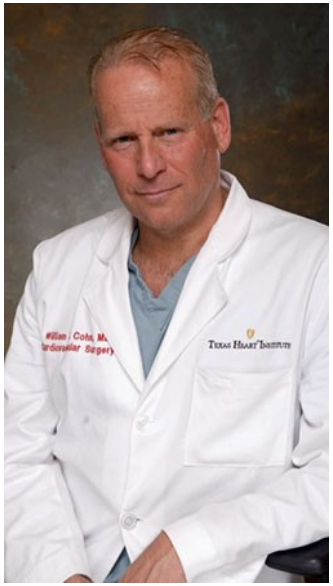
- Task : *document the final design*

- **Output : final written, oral reports to client containing** { *description of design process*, *drawings and design details*, *fabrication specifications* }

Prove that your idea works

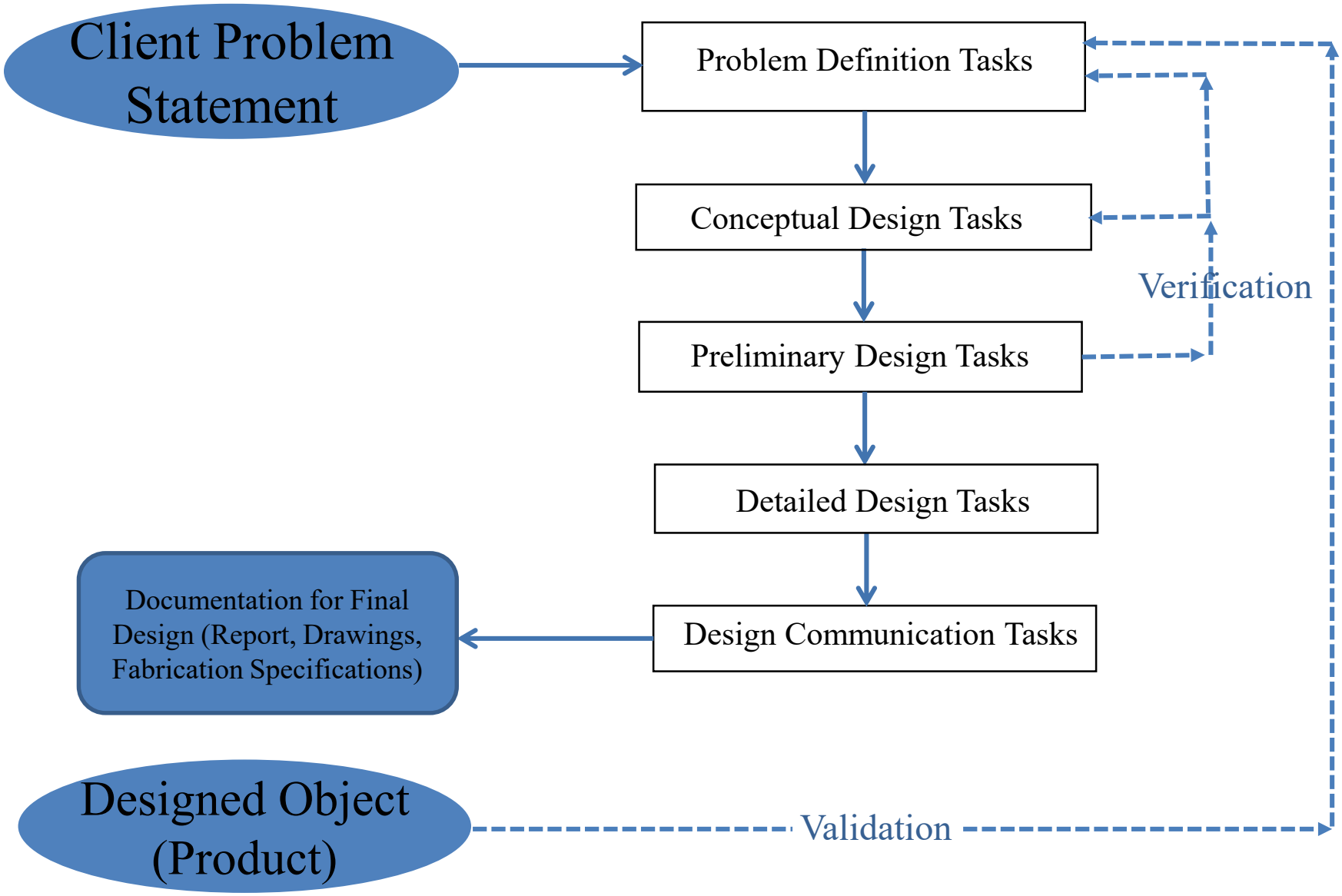
The first pulseless total heart replacement device in a human patient.

90 US patents granted or pending, and another 60 international patents for his medical innovations



William Cohn

Professor, Baylor College of Medicine
Texas Heart Institute


Client Problem Statement
Problem Definition Tasks
Conceptual Design Tasks
Preliminary Design Tasks
Detailed Design Tasks
Design Communication Tasks
Documentation for Final Design (Report, Drawings, Fabrication Specifications)
Designed Object (Product)
Verification
Validation

Product definition tasks:

- Clarify objectives
- Establish user requirements
- Identify constraints
- Establish functions