2808120 - Advanced Ship Design
Lesson 1 - Ship Design

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Outline

1. Design
   - Stages
   - Evolution
   - Environment
   - Phases
2. Technical Office
3. Mission Requirements
4. Machine Learning Techniques

Design

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Generative Modelling

"Design, while having many meanings, in this context means to prepare calculations, technical model/documentation (drawings), specifications, and to support these with experimental testing as required."

[Lam10]

Design

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1. Concept Design
2. Preliminary Design
3. Contract Design
4. Detailed Design
5. Production Engineering

Concept Design

- Research, Requirements, Feasibility, Target Study.
- Conceptualisation.
- Elaboration of conceptual sketches and models.

Ship type, deadweight, propulsion type, service speed, etc.

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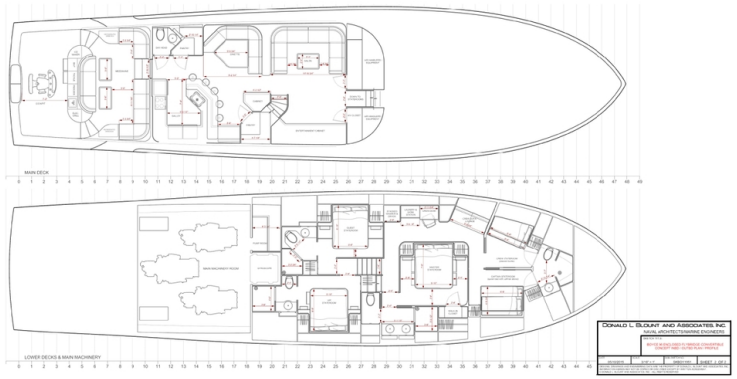
Front-End Engineering Design (FEED)

- Refining the concept, Common Regulations, Calculations.
- Profiled target.
- Elaboration of schematics, diagrams and layouts.



Main hull dimensions, Coefficients, etc. $\longrightarrow$ Idea of the building and exploitation cost.

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Information Produced:

- General Arrangement, definition of the compartment configuration.
- Body Plan, certain accurate definition of stability and of the cargo capacities.
- Predicted Propulsive System solution.
- Lightship weight.
- Cost estimation of building and exploitation of the design.

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- Requirements and Legal assessment.
- Target acquired.
- Shipbuilding contract.

Elements that define the general aspects of the ship and its equipment. Parts involved here will be the Owner and Builder (+Technical Office)

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Information Produced:

- Ship Specification.
- General Arrangement.
- Body Plan $\rightarrow$ $towingtankmodel.Classification()$
- Resistance and Stability calculations.
- Piping (ballast, bilge, cooling, ...) $\rightarrow$ $StructuralDrawings(midships, b$

Detailed Design

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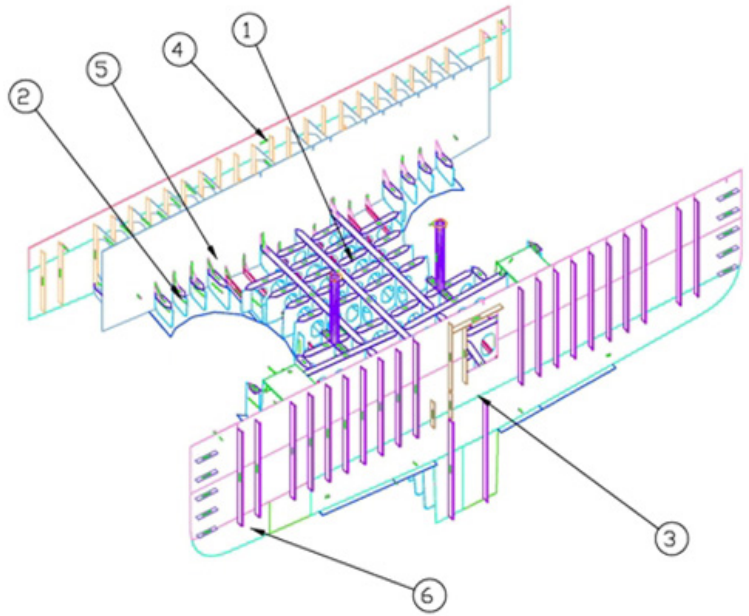
- Detailed procedure of tasks from previous steps.
- Materials assortment.
- Modelling, Simulation, Drawings and Specifications. Previous Certification.



Documentation detailed to sufficiently be manufactured and assembled.

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Information Produced:

- Detailed definition of appendage, fairing, structural framing, seams and butts plating.
- Material Specification.
- Structural drawings for block production.
- Nesting, bending and assembly of plates and stiffeners.
- Piping isometric drawings to be manufactured and assembly arrangement.

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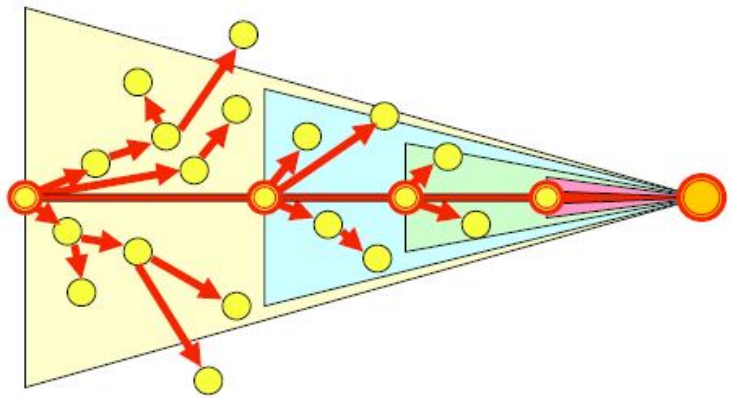
- Certification, Assessment, Optimisation.
- Monitoring and management.
- Building.

Evolution

- Concept Design
- Preliminary Design
- Contract Design
- Detailed Design
- Production Engineering



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Tasking

Repetition of a compendium of several identical, similar or new tasks as the phases/stages progress.

Evolution

Design Spiral

Ship design is an iterative process (specially in early stages).

In practice, the process is not sequential, unless the design is developed entirely by one person.

Furthermore, the steps may not be performed in the prescribed order.

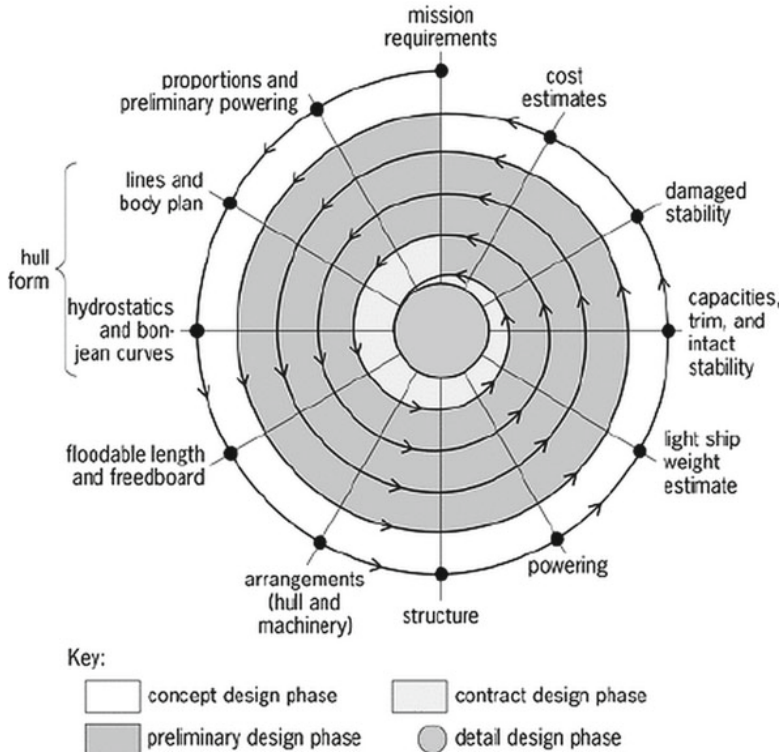

Figure 1: Design Spiral. Extracted from [Pap14]

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Design Development Process (Early Stages)

- Rather unpredictable.
- Usually a preferred sequence for the tasks.
- Milestone Updates.

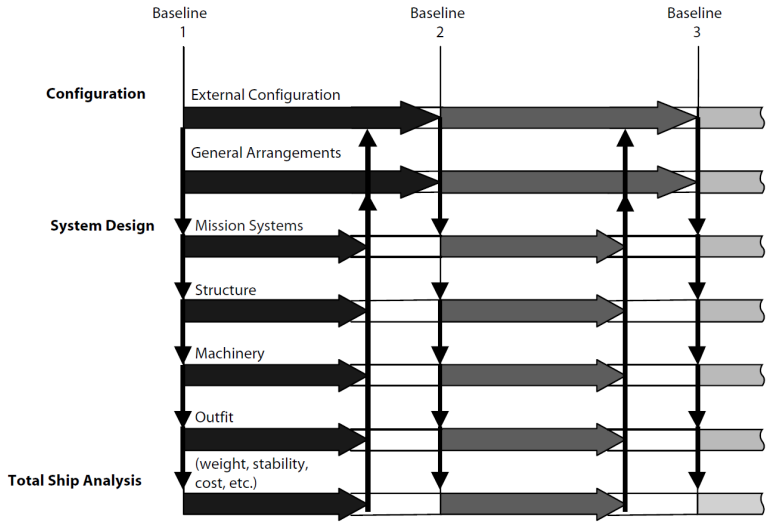

Figure 2: Design Development Process.

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Factors

- Economic trends.
- Current and pending government policies and regulations.
- Status of international regulations on matters such as pollution control.
- Breadth and depth of the vendor base for major equipment items.
- Management of the design team (shipyard or a design agent).
- Meeting Shipowners requirements.

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Standard Roles involved

- Naval Architect.
- Marine Engineers.
- CAD designers.
- Structural Engineers.
- Electrical Engineers.
- Shipyard personnel(construction and production planning) experts.
- Equipment Vendors.
- Analyst/Consultant (CFD/FEA, propeller, acoustics, reliability, human factors).
- Certification Society.
- Etc.

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Standard Roles in short

- Ship Owner
  - Starts and finishes the process.
  - Develops the concept design.
  - Contracts the design.
  - Contracts the shipbuilder.
  - Owns the ship after construction.
- Ship Designer
  - Develops the design and technical documentation.
  - Design office or shipyard's department.
  - Undertake and sub-contract design's parts.
- Ship Builder
  - Shipyard which build the design.
  - Product Engineering (sub contract Detail Design).
  - Subcontract to other yards.
- Classification Society.
  - Establishes the rules.
  - Homologates the design and building.
  - Certificates the ship.

Environment

Powerful assets (Integrated System Solutions)

- Database / Experience.
- Pre-processing / CAD.
- Analysis / CAE.
- Post-processing / Rendering.
- Automatisation / Optimisation.

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Classification Entity

- Society Standards.
- National Regulations.
- International Regulations.

Those can have significant influence on the design, even in early stage.

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Shipowner's Requirements

- Time.
- Cost.
- Know-How.
- Software limitation.
- Physical(shipyard limitation, health structure monitoring, ports).

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Shipowner's Requirements - Attributes (What to trade)

- Prime cost.
- Operating cost.
- Manning.
- Producibility.
- Operability.
- Maintainability.
- Reliability.
- Mission capability.
- Sustainability.
- Supportability.
- Risk (cost schedule and technical).

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Innovation (Uniqueness)

- State of the art.
- Innovation and research.
- Novel purpose.
- Development of new technology.

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1. Basic Design
   1. Concept Design
   2. Preliminary Design
   3. Contract Design
   4. Detailed Design
2. System Design
   1. Transitional Design
   2. Workstation / Zone Information Preparation

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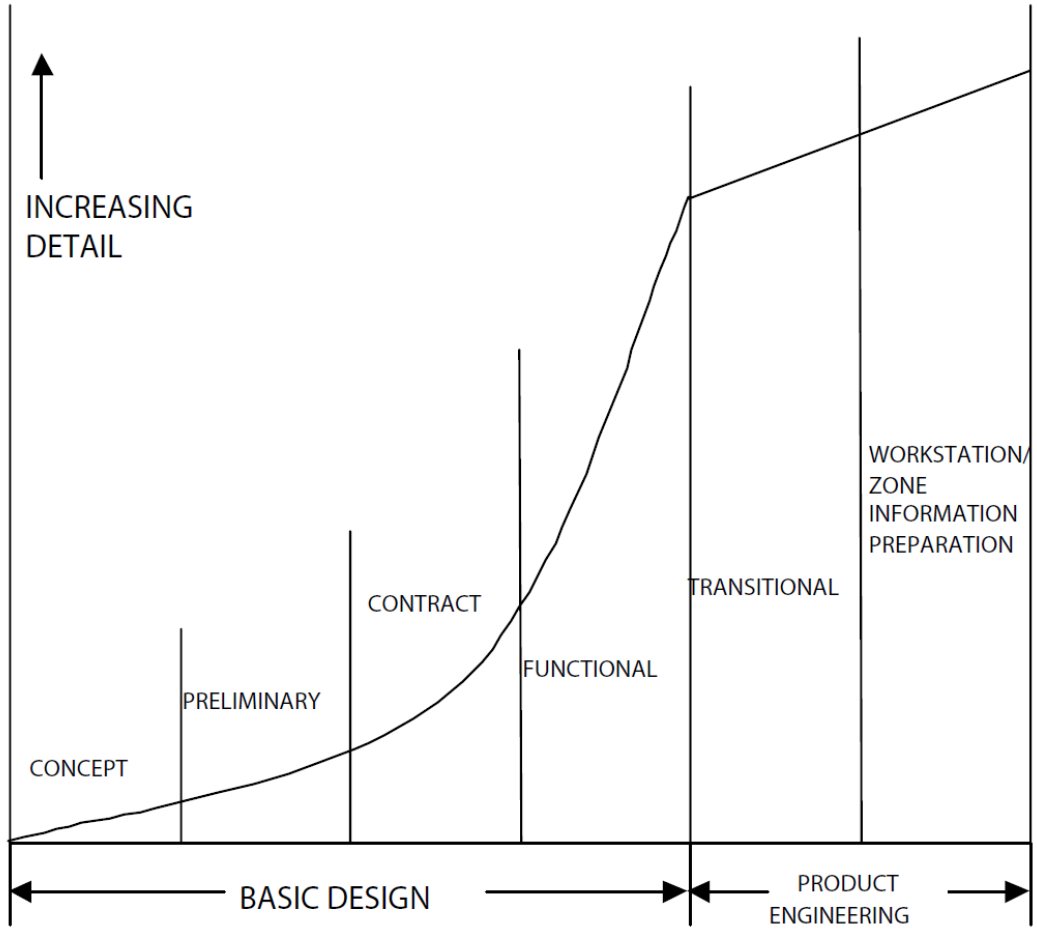

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Documents

- Feasibility Study.
- Cost Study.

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Shipowner requirements (Optimisation)

- Fleet.
- Goods.
- Routes.
- Budget.

Produces a transportation system model.

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Transportation system model

1. Time Calculus
   - Loading/Offloading Cargo
   - Routing
   - Schedule Generation
2. Cargo Calculus
   - Cargo Capacity
   - Fuel Consumption
3. Cost Calculus
   - Construction
   - Operation
   - Benefits
   - Amortization

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Influence factors

- Type of cargo.
- Type of port.
- Type of route.
- Type of ship.

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Type of Cargo

It may introduce several limitations regarding

- Material limitation.
- Regulations.
- Combination of different cargo.

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Type of Port

It may introduce several limitations regarding

- Depth.
- Security Level.
- Services.
- Affluence (good/bad).

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Type of Route

It may introduce several limitations regarding

- Canals
- Tides.
- Special Navigation.
- Ice Navigation.

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Type of Ship

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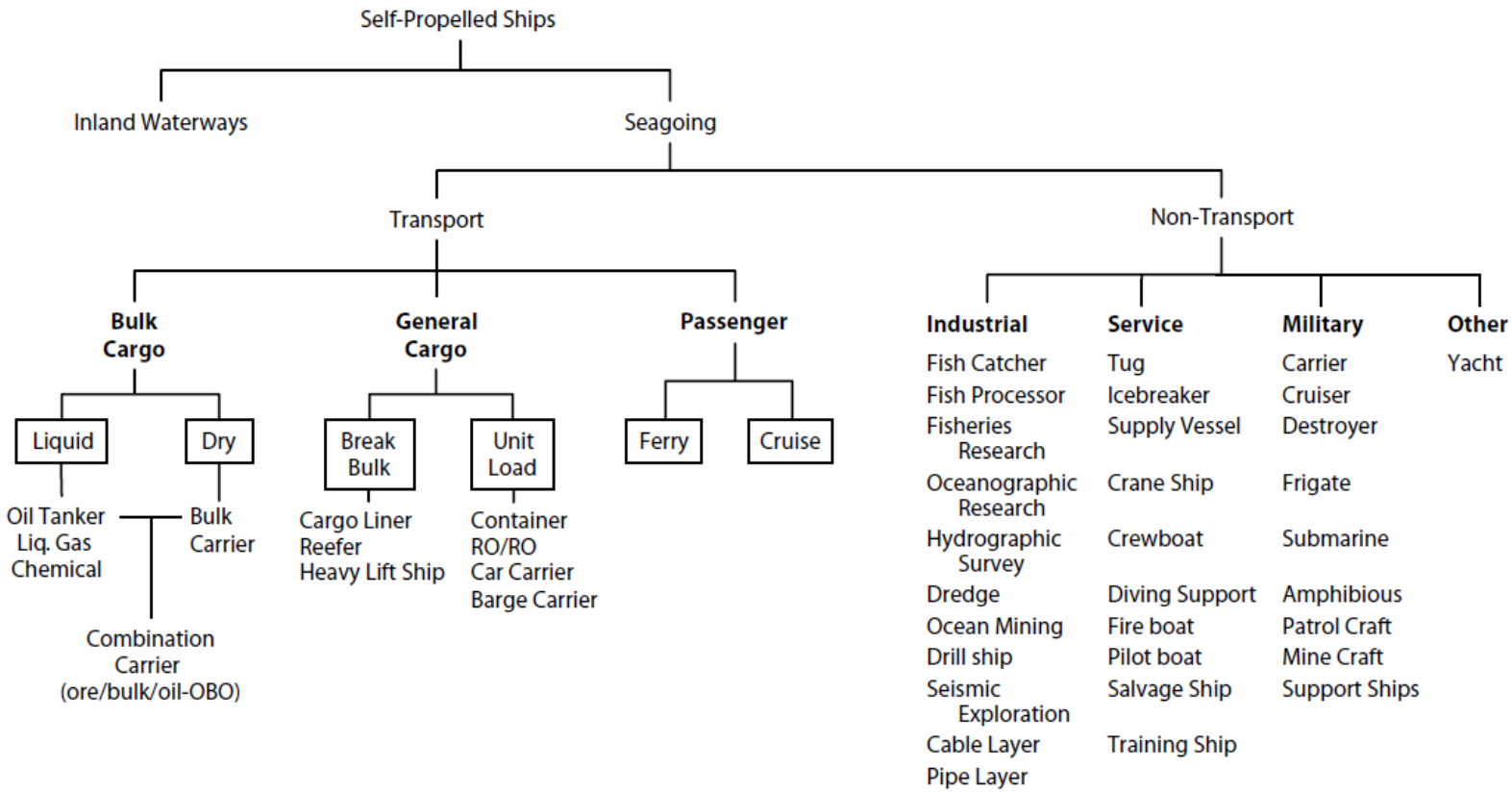

Figure 3: Ship type categories.

Figure of Merit is a quantity used to characterise the performance of a device, system or method, relative to its alternatives.

- Minimum Production Cost (+Shipyard, -Shipowner)
- Minimum Investment Cost (-Shipyard, +Shipowner)
- Life Cycle Cost (No charting, MIC + Maintenance Cost)
- Minimal Charting Required (Cost per charting, undetermined future)
- Amortisation Cost
- Payout Cost

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Feasibility Study

- Performance specification (initial draft)
- Body plan and appendage sketch
- Area/volume summary
- Concept general arrangement drawings (space *blocks* allocated by function)
- Topside arrangement sketch
- Payload definition
- Description of mission-critical systems and features
- Weight estimate
- Concept midship section
- Propulsion plant description
- Machinery arrangement sketch
- Electric load analysis and generated selection
- Simplified one line diagrams
- Master Equipment List (MEL)
- Speed-power curve
- Manning estimate
- Endurance fuel analysis
- Estimates of critical performance aspects, as required
- Cost estimate
- Technical risk assessment and risk management plan

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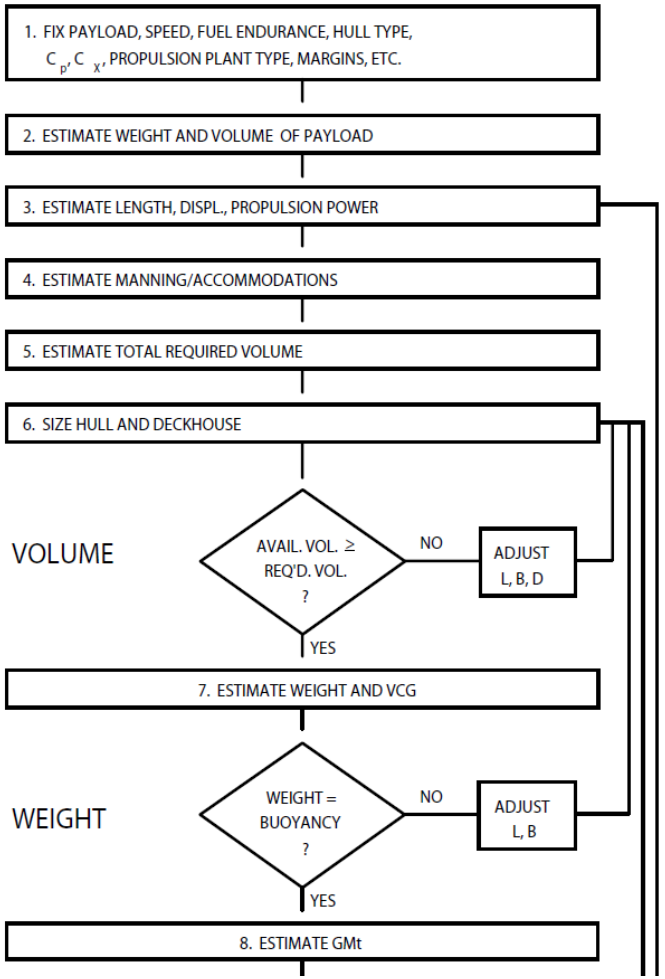

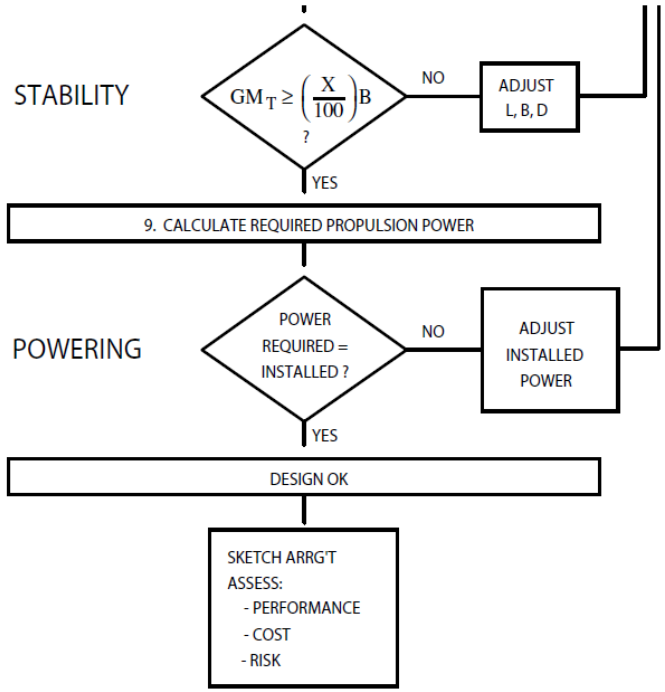

Preliminary Design

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Assess Conceptual Design and Specification of it.

Objectives

- Validate top level ship requirements.
- Develop second tier requirements.
- Select major systems.
- Quantify ship performance.
- Reduce/eliminate highest technical, cost and schedule risk.
- Refine investment and operating cost estimate.
- Develop a draft version of the construction strategy.

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Trade-off studies

- Hull proportions (L/B, B/D...).
- Hull profiling (transom vs cruiser stern, bow bulb vs not...).
- General arrangement.
- Propulsion plant type (low speed diesel, medium speed diesel, gas turbine, integrated electric...).
- Deckhouse size and location.
- Mission-critical payload features (hardware components, space allocation, arrangement...).
- Hull structural configuration.
- Crew size.

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Overview

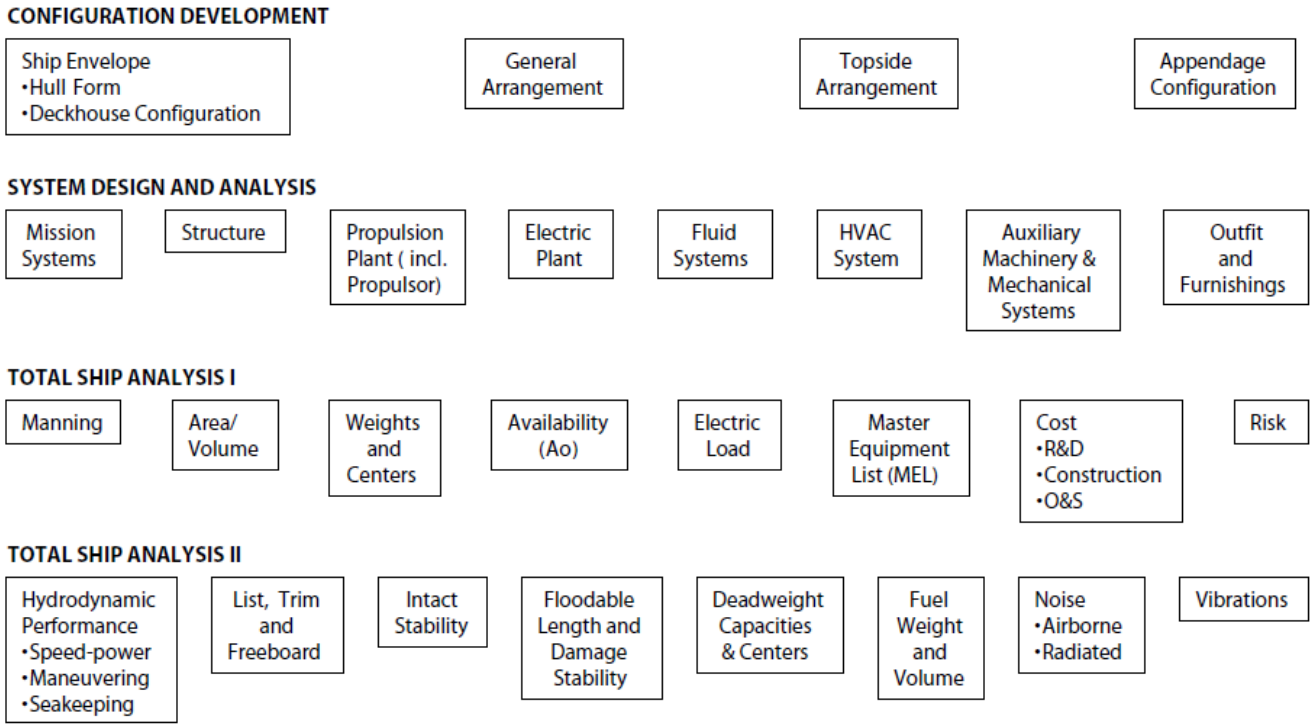

Figure 4: Overview of task categories.

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Objectives

- Confirm ship capability and cost to the prospective shipowner
- Provide a meaningful and accurate bid package for shipbuilders.
- Provide criteria for shipowner acceptance of the ship.

Contract Design

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For each system

- From higher level requirements derive the lower tier performance requirements.
- Develop and evaluate alternative system concepts.
- Complete engineering work.
- Develop schematics and specifications.

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Template (General Data/Preamble)

- Type of ship.
- Principal features.
- Deadweight.
- Capabilities and Gross register tonnage.
- Loadcases.
- Speed and autonomy.
- Crew and cabinets.
- Vibrations and noise.
- Materials, year of constructions and trials.
- Classification, regulations and certificates.

The rest are specific chapters regarding the ship design.

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Specific tasks

- Form generation.
- Lightweight and gravity center.
- General arrangements and tanks.
- Capabilities and Gross register tonnage.
- Structure.
- Propulsion and powering.
- Propulsion plant and other systems.
- Manoeuvring and seakeeping.
- Intact and damaged stability.
- Cost analysis.

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Form Generation

- Schematics and plans.
- Hydrodynamic analysis.

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General Arrangements

- Decks.
- Bulkheads.

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Capabilities and Gross register tonnage

- Tank dimensioning.
- Gross register tonnage calculus.
- Freeboard calculus.

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Structure

- Midship frame.
- Rest of the structure.

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Propulsion and powering

- Powering.
- Propulsion equipment.
- Manoeuvring equipment.

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Manoeuvring and seakeeping

Different features regarding manoeuvring and seakeeping.

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Intact and damaged stability

- Loadcase definition.
- Intact stability analysis.
- Damaged stability analysis.

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Cost Analysis

Economic assessment. A budget has to be generated.

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Generated documents model

Performance specification

Lines drawing and appendage sketch

Area/volume report (req'd vs. actual)

General arrangement drawings (to individual compartment level)

Topside arrangement drawing

Line of sight analysis

Payload definition

Descriptions of principal ship systems and features

Weight report (3-digit level, KG and LCG)

Structural midship section

Preliminary scantling drawings

Propulsion system analysis

Machinery arrangement drawings

Shafting arrangement

Preliminary propulsor design

Electric load analysis

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HVAC load analysis
One line diagrams
Typical space arrangements
Deck systems arrangements
Ship control and communications systems analysis
Preliminary Master Equipment List (MEL)
Preliminary ship manning analysis
Stability analysis, intact and damaged
Speed-power curves
Endurance fuel analysis
Seakeeping and maneuvering analyses
Model test plan
Other performance estimates, as required, for example, radiated noise
Preliminary availability analysis (Ao)
Maintenance concept
Supportability concept

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Generated documents model

T&E plan (draft)

Preliminary safety analysis

Build strategy (draft)

Shipyard production specification (Shipbuilding Policy)

Cost estimate

Technical risk assessment and risk management plan

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Structure of a contract

1. Subject of Contract
   - Description and main characteristics of the ship.
   - Yard number.
   - Registry and Classification of the ship.
   - Decision of the Classification Society.
   - Sub-contracting by the yard.
2. Inspection and Approvals.
3. Modifications.
   - Due to the Owner.
   - Due to the Builder.
   - Due to Regulating Offices or to the Classification Society.
4. Sea Trials

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5. Guarantee for Speed, Cargo Carrying Capacity and Fuel Consumption
   - Penalties.
   - Limit of Acceptance.
   - Rewards.
6. Delivery of the Vessel.
   - Place and Date.
   - Documentation.
   - Penalties and Rewards.
   - Force Majeure.
7. Price

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8. Property
   - Generic drawings.
   - Specifications.
   - Detail drawings.
   - Ship.
9. Insurance
10. Default by Purchaser
    - Penalties due to missing payments, delivery of the ship, deliverance owner's supplies.
11. Default by the Contractor
    - Devolution of instalments paid and penalties.
12. Guarantee after Deliverance
13. Contract Expenses
14. Patents

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15 Interpretation, Reference to Expert and Arbitration
16 Condition for the Contract to Become Effective
17 Legal Domicile
18 Assignment
19 Limitation of Liability
20 Mail Addresses

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Compliance

- International Convention for the Safety of Life at Sea.
- International Convention on Load Lines.
- International Convention for the Prevention of Pollution from Ships.
- IMO Standards.
- Gross Register Tonnage Regulations.
- International Regulations for Preventing Collisions at Sea.
- Applied International/National Regulations.

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Functional Design

- Definition of schematic designs and functional arrangements.
- Definition of materials and equipment.
- Specific construction plans (Classification Society).
- Validation of submitted schematics.
- Documentation for trials.

Detailed Design

Detailed Design (schematics)

- Elaboration process.
- Block construction.
- Piping.
- Nesting.
- Modular construction.
- Mock-up.
- Wiring.

Detailed Design

Hull

General arrangement- Compartment and access (C&A) drawings

Outboard profile

Lines drawing

N.A. drawings, for example, hydrostatics, cross curves of stability, docking drawing

Block arrangement and list

Frame body plan (based on faired lines)

Structural block drawings with scantlings

Major foundation drawings

Welding plan

Hull fitting drawings

Hull weights, centers, and block lifting data

Lists of hull outfit

Lists of hull fittings

Nameplates and Notices

Summary paint schedule

Summary deck covering schedule

Summary hull insulation schedule

Furniture list

Plumbing and fixture list

Galley arrangement

Accommodation arrangement

Steering gear arrangement

Rudder and rudder stock arrangement

Rudder and propeller lifting gear arrangement

Anchor handling arrangement

Mooring arrangement

Life-saving equipment arrangement

Hull piping system diagrammatics

Purchase Technical Specifications (PTS)

Advanced Material Ordering (AMO) Lists

Steel List per block

Machinery and Piping

Machinery arrangement

Shafting arrangement

Stern tube arrangement

Machinery space and wheelhouse control console arrangement

Machinery piping system diagrammatics

Diesel exhaust arrangement

Lifting gear in machinery space

Machinery and pipe insulation schedule

Unit and equipment foundations

Machinery and foundation weights

Purchase technical specifications (PTS)

Advanced material ordering (AMO) Lists

Electrical

Electrical Load analysis

One-line diagram

Short circuit analysis

List of motors and controllers

List of feeders and mains

Electrical equipment and installation diagrams

Switchboard drawings

List of Portable electrical equipment

Electrical system weights

Purchase Technical Specifications (PTS)

Advanced Material Ordering (AMO) Lists

HVAC

Heating and cooling analysis

HVAC diagram and equipment list

HVAC insulation schedule

HVAC system weights

Purchase Technical Specifications (PTS)

Advanced Material Ordering (AMO) Lists

Production Planning

Work station information plan and schedule

Block outfitting and erection schedule

Zone outfitting schedule

Tests and Trials schedule

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The production project definition

- Has to describe the means to ensure the production of the ship.
- Constraints of the very shipyard.
- Use of standard materials.
- Optimise the number of process.
- Specify the storage, zoning, etc.

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Integral construction

- Avoiding traditional sequence of flow work.
- Project accommodation to the structure of work.
- Multitasking.

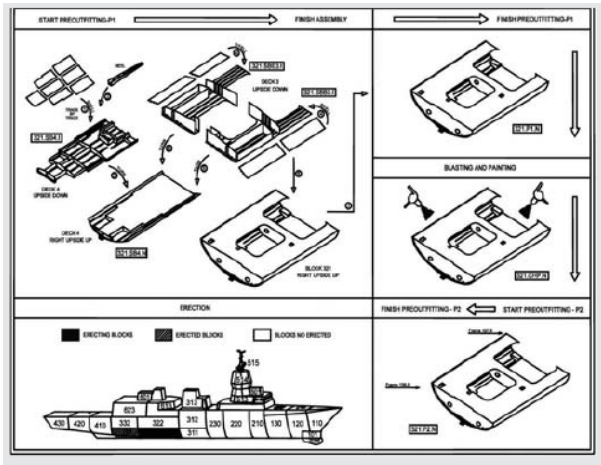

Figure 5: Intermediate assembly.

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Organisation Structure

- Functional Units.
- Project Teams.
- Hybrid.

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Departments (naval architecture, hull, electricity, etc.)

Pros

- Focus knowledge and more efficiency in their area of work.
- Knowledge share.
- Small personnel.
- More flexibility and better use of resources.
- Continuity.

Cons

- Difficulty to work on large projects (subdivided tasks).
- Responsibility clashes.
- Multitasking.
- Pure working force, not management or planning.
- Dependency on working load.
- Slow adaptability to modification in the current project.

Project Teams

Teams composed of mini-departments (naval architecture, hull, electricity, etc.)

Pros

- Full control on the project.
- Hierarchy.
- Communication/coordination problem reduction.
- Clear responsibility.

Cons

- Function duplicates.
- Difficulty on forming such groups.
- Bigger personnel.
- Highest cost.
- Not acquisition of know-how.
- Project breaks result in idling workers.

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Overview

- Types of ships depending on their mission requirements.
- Length determination.
- Analytical Calculus.
- Empirical Calculus.
- Scaling.
- Dimension limits.
- Critic Dimension.

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Types of ships depending on their mission requirements

- Passanger(I).
- Cargo(II).
- Fishing(IV).

R.D. 1837/2000 and SOLAS.

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Length determination

- Requirements(specific or cargo).
- F_n and C_B relationships to relate drag resistance and length.
- Ratios (beam, draught, length, displacement).

Most expensive dimension.

$$L_{pp} = 0.97 L_{WL} \tag{1}$$

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Analytical Calculus (conditioned dimensions)

- Forepeak.
- Machinery room.
- Auxiliary room.
- Cargo.
- Rearpeak.

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Empirical Calculus

- Jaeger.

$$\sqrt{L_{pp}} = (p+q)^{1/3} + (p-q)^{1/3}$$

$$p = b\Delta^{1/3} v \tag{2}$$

$$q = b\Delta^{1/3}\sqrt{v - 2\Delta^{1/3}}$$

Small craft: b=2/3
Intermediate length craft: b=5/6
Long length craft: b=1

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Empirical Calculus

- Maglioni.

$$\begin{aligned} L_{pp} &= a^4\sqrt{DW} \\ L_{pp} &= b^4\sqrt{DW}\sqrt{0.1v} \\ L_{pp} &= c^4\sqrt{\Delta} \\ L_{pp} &= d^4\sqrt{\Delta}\sqrt{0.1v} \end{aligned} \tag{3}$$

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	MÍNIMO	NORMAL	MÁXIMO
a	13,4	14,2	15,6
b	10,8	11,4	12,6
c	12,9	13,6	15,1
d	10,3	10,9	12,0

Figure 6: Maglioni parameters.

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Empirical Calculus

- Posdunine-Van Lammeren.

$$L_{pp} = c(\frac{v}{v+2})^2 \sqrt[3]{\Delta} \tag{4}$$

Result in ft .

v(11 - 16.5 knots), 1 propeller, c=23.5

v(15.5 - 18.5 knots), 1 propeller, c=24

v(<20 knots), 1 propeller, c=26 (passenger)

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Scaling

Basis Ship (B) and Projected Ship (P):

$$\frac{L_B}{\sqrt[3]{\Delta_B}} = \frac{L_P}{\sqrt[3]{\Delta_P}}$$
$$\frac{L_B}{\sqrt[3]{\nabla_{C,B}}} = \frac{L_P}{\sqrt[3]{\nabla_{C,P}}} \quad (5)$$

$\nabla_{c,i}$ is the cargo volume. Also the DW can be used.

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Dimension limits

- Shipyard
- Traffic
- Canals
- Port
- Sway movement.
- Classification Societies, National Authorities and International Organism.
- Aerial draught.

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Critical Dimension

- Deadweight ships (weight, L_{pp}, B, D)
- Volume ships (Cargo, L_{pp}, B, D)
- Surface ships (Ro-Ro, L_{pp}, B)
- Container ships (volume, L_{pp}, D, B)
- Special transport ships (weight, L_{pp}, B, D)
- Service ships (stability and velocity)

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Deadweight ships (weight and low stowage density)

Limit value cargo (density)

$$LDC = \frac{DWT_{Cargo}}{\nabla_{Cargo}} = \frac{\frac{DWT_{Cargo}}{DWT} \times \frac{DWT}{\Delta}}{\frac{\nabla_{Cargo}}{\nabla} \times \frac{\nabla}{\Delta}} \quad (6)$$

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Deadweight ships (weight and low stowage density)

$C_B \rightarrow T$ and $C'_B \rightarrow D$

$$LDC = \frac{DWT_{Cargo}}{\nabla_{Cargo}} = \frac{\frac{DWT_{Cargo}}{DWT} \times \frac{DWT}{\Delta}}{\frac{\nabla_{Cargo}}{\nabla} \times \frac{C'_B D}{\rho C_B T}} \quad (7)$$

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Deadweight ships (weight and low stowage density)

$C_B \rightarrow T$ and $C'_B \rightarrow D$

$$C'_B = C_B + (1 - C_B)\frac{0.8D - T}{3T} \tag{8}$$

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Volume ships (volume and high stowage density)

Critical dimensions would be freeboard and intact stability.

Influenced by B/D (stability) *to* L/B

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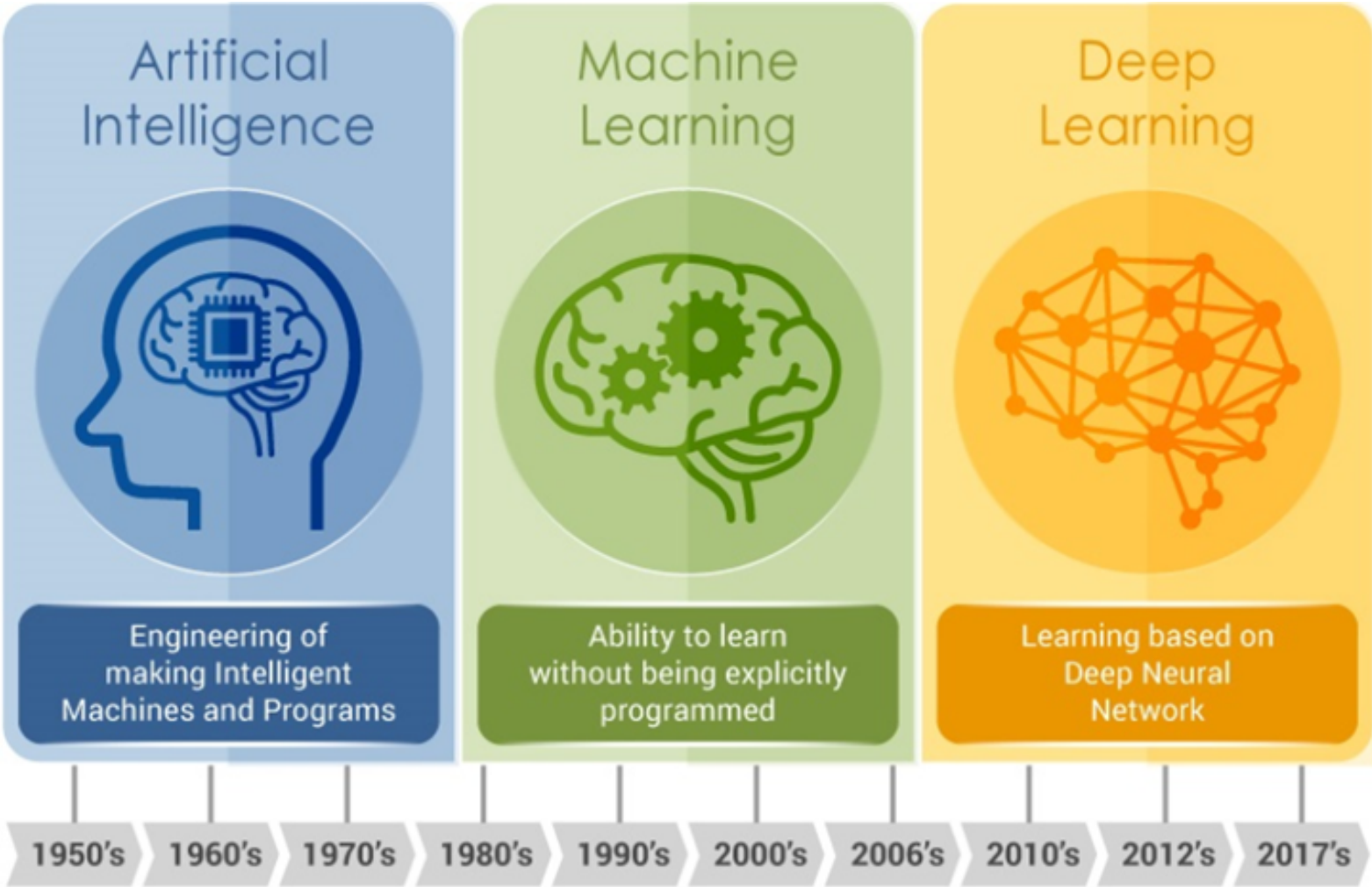

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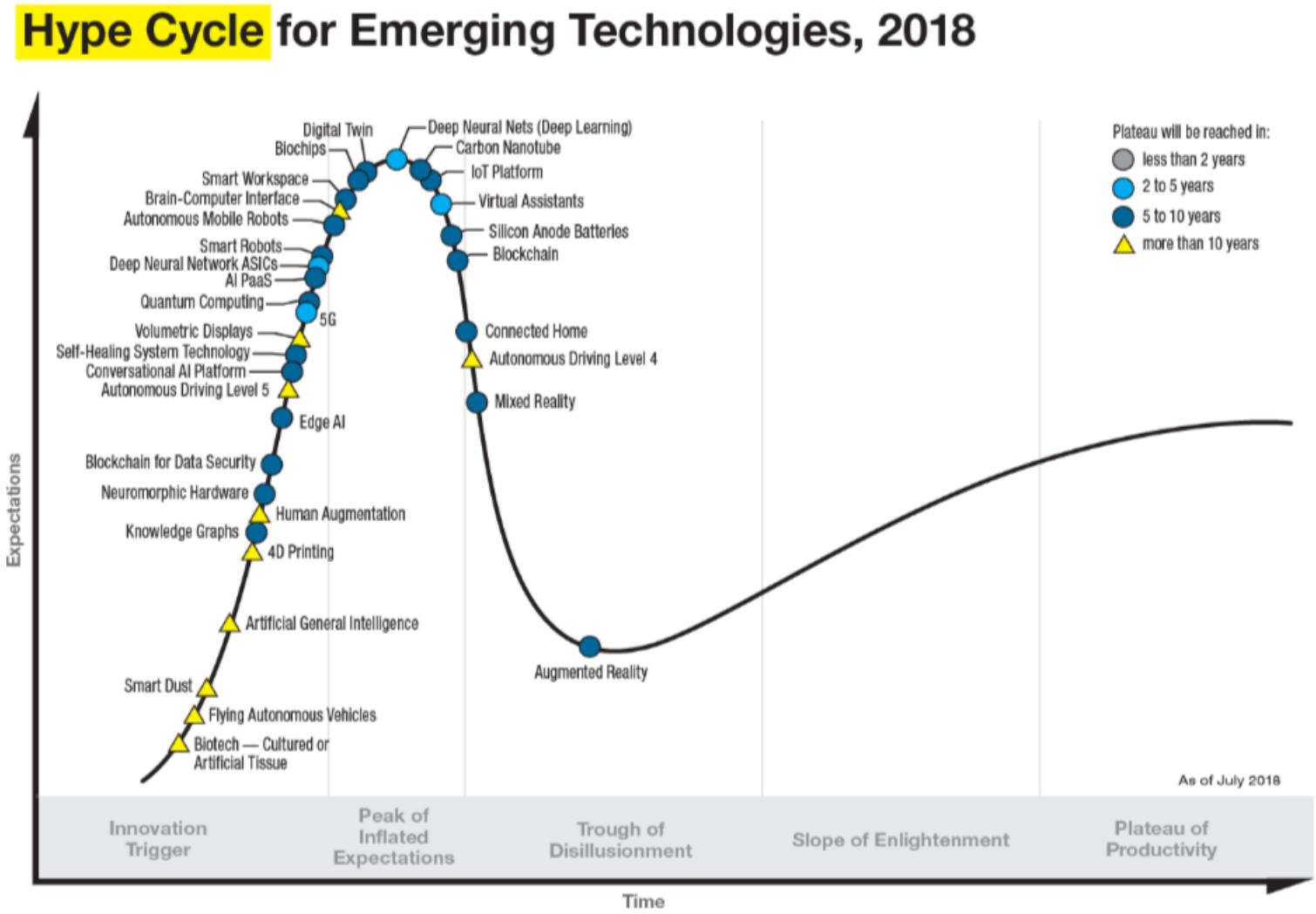

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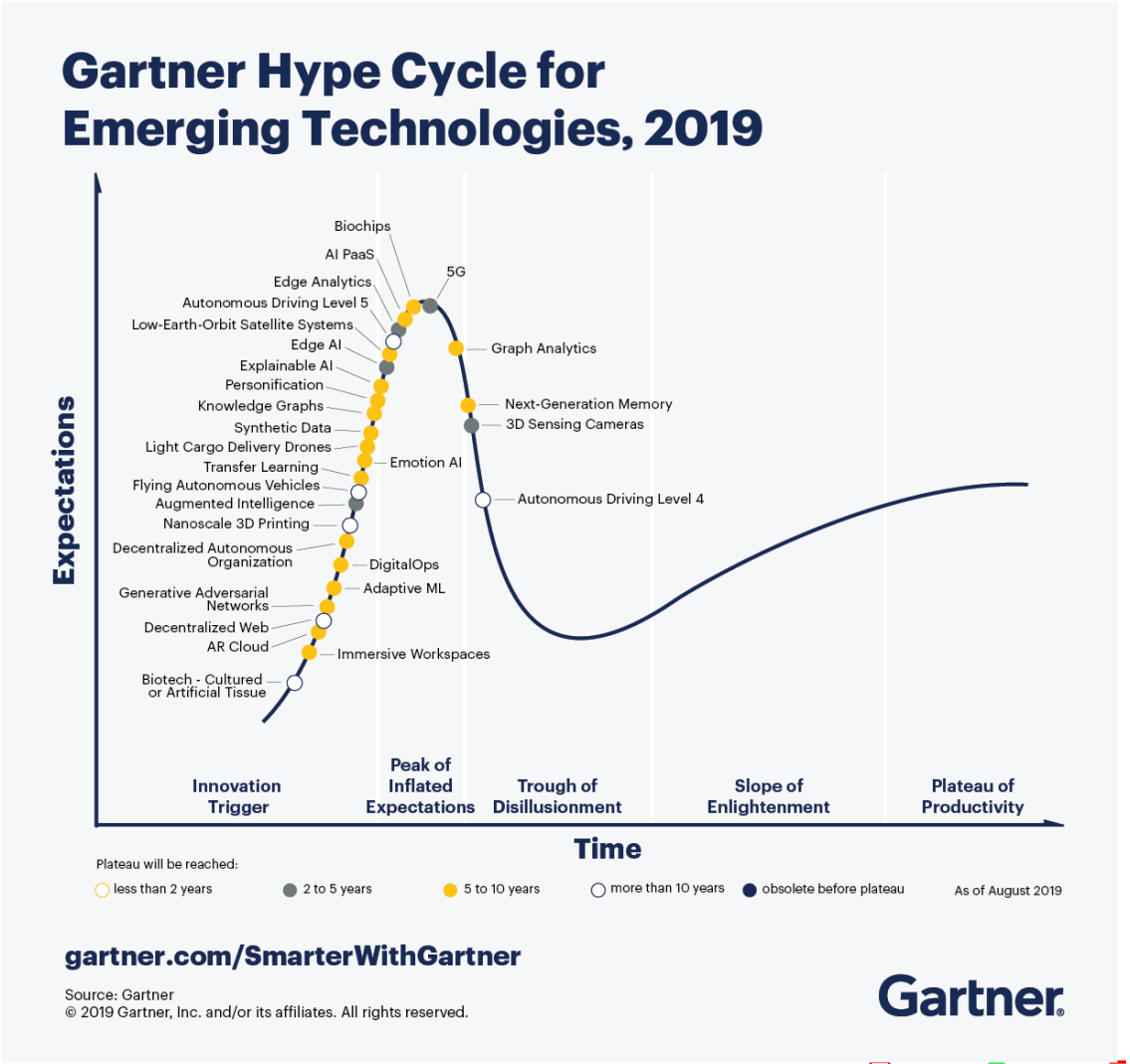

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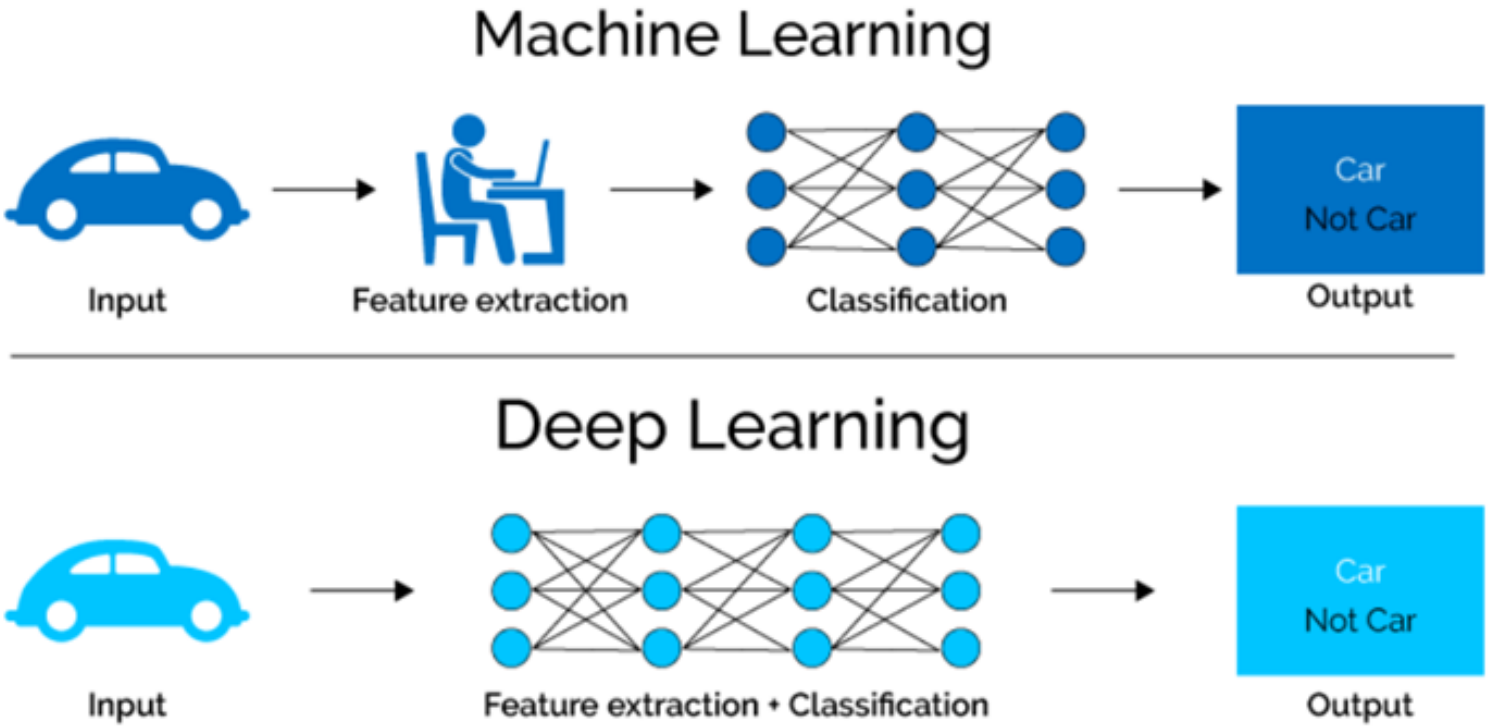

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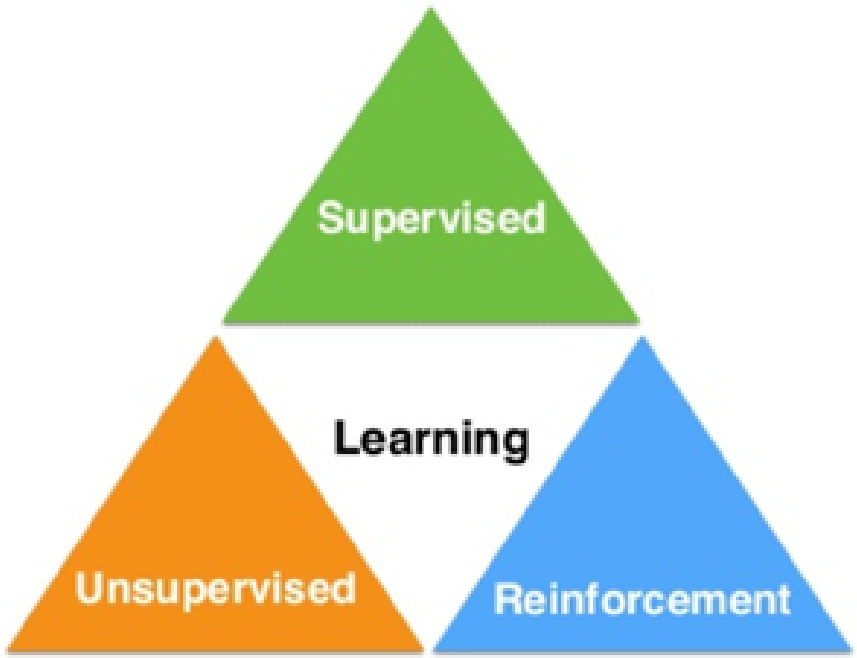
- Labeled data
- Direct feedback
- Predict outcome/future



- No labels
- No feedback
- "Find hidden structure"

- Decision process
- Reward system
- Learn series of actions

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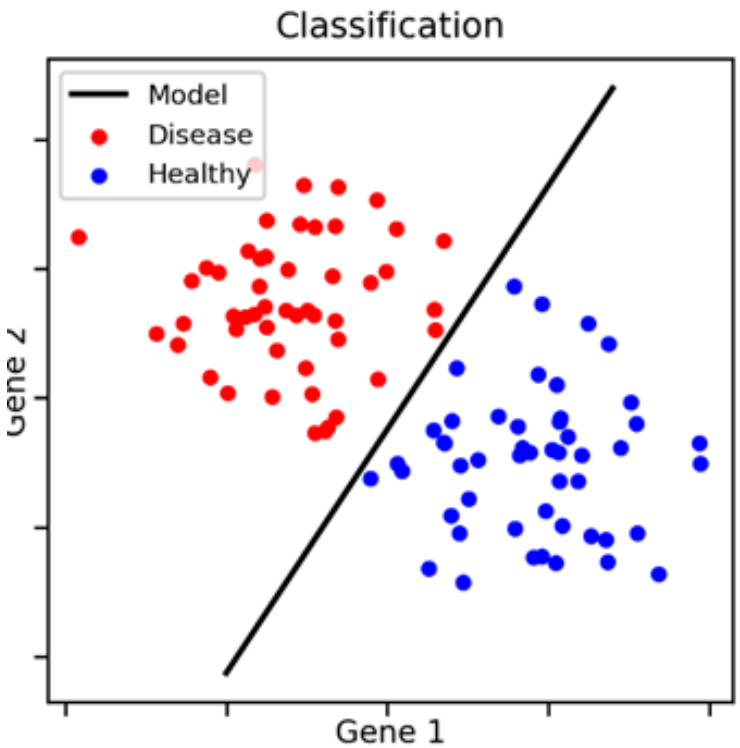

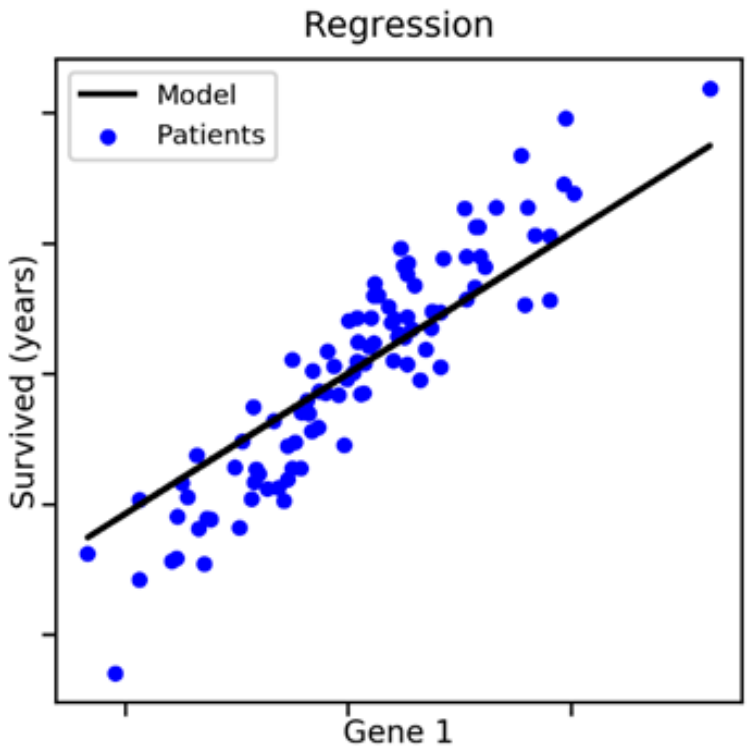

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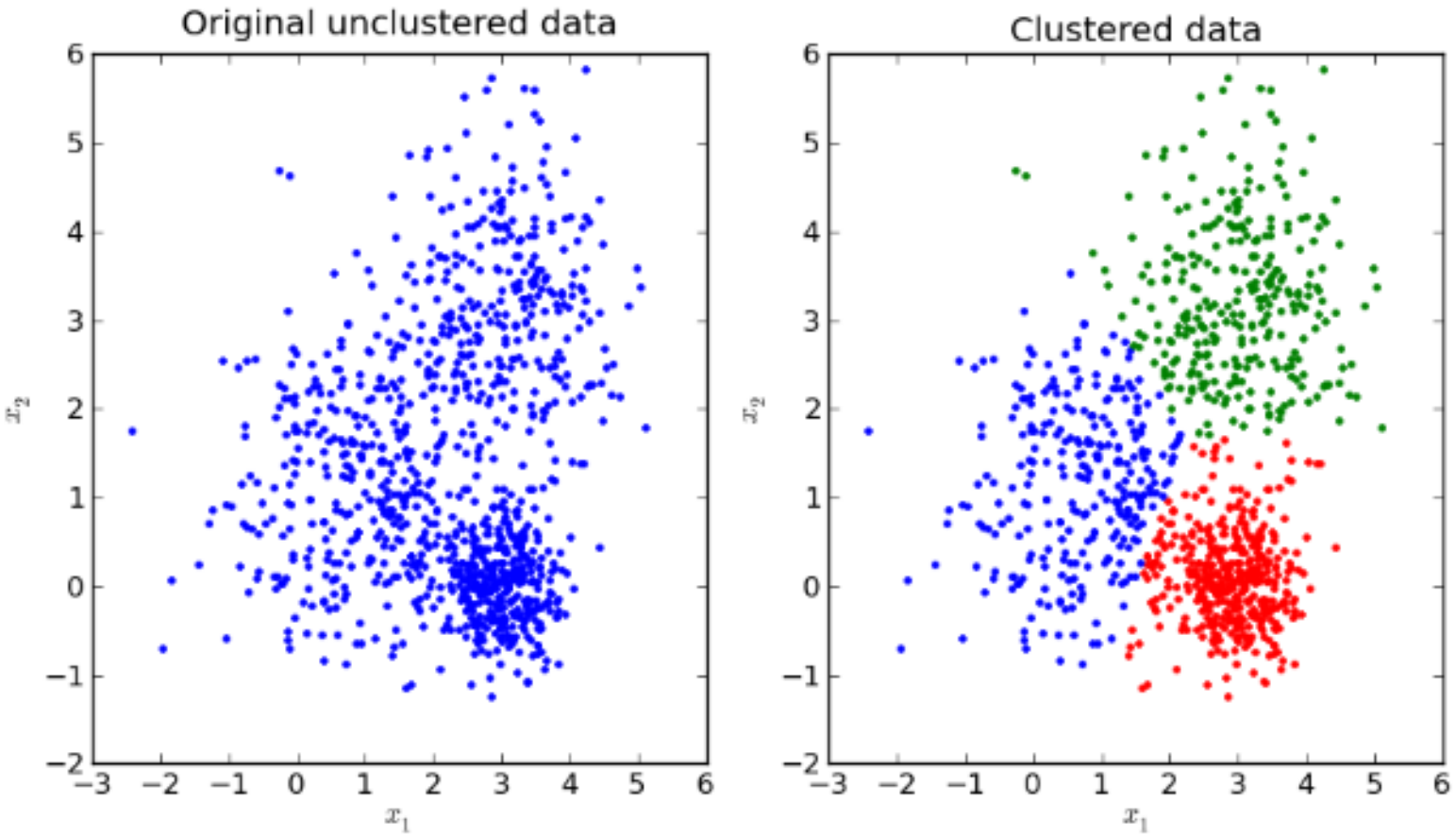

A computer-generated program showing k-means clustering [3]

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THE END

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