63° Congreso Internacional de Ingeniería Naval e Industria Marítima
Madrid, 24-26 abril, 2024
TRANSFORMANDO LOS OCÉANOS: INNOVACIÓN e ingeniería naval para un mundo CONECTADO y SOSTENIBLE

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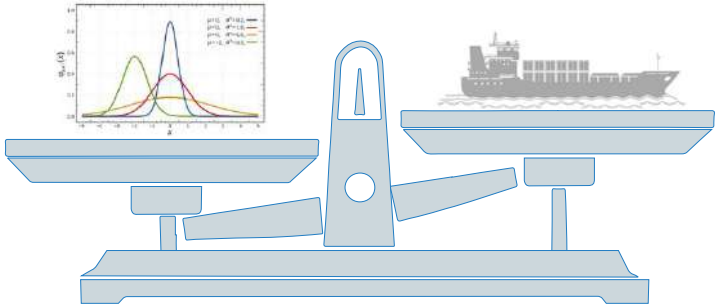
WEIGHT CONTROL BASED ON UNCERTAINTIES ASSESSMENT



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LIGHTSHIP WEIGHT CONTROL

WEIGHT CONTROL

Weight control is all actions to ensure that the distribution and weight of the ship are according to naval architecture requirements

- *Changes on ship operation* – *loss of cargo capacity*
- *Weight corrections* – *lighter materials*
- *Changes on dimensions* – *lenght enlargement*

CHALLENGES

Optimization of deadweight to lightweight ratio is a necessity for new ships.
Integration the new fuels and propulsion system

LIGHTSHIP WEIGHT CONTROL

MARGIN

PROJECT DEVELOPMENT DEPENDENT

- *Covers the inherent limits of precision*
- *Calculation mistakes*
- *Unknow additions / Project development (statistical)*

INDEPENDENT OF PROJECT STAGE

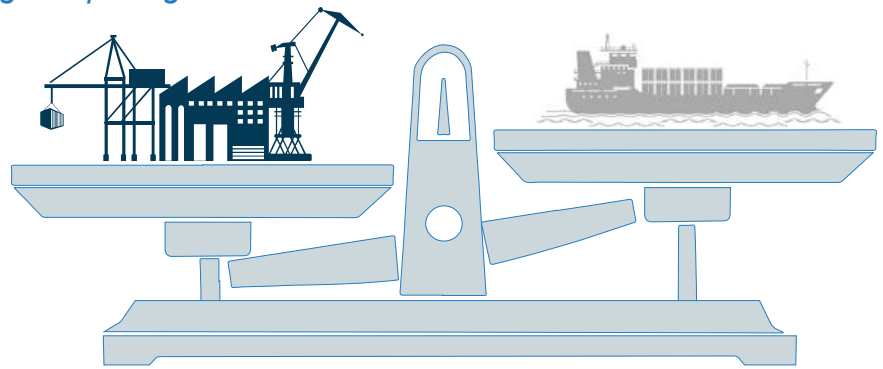
- *Bulk items*
- *Inclining experiment uncertain margin*

CHALLENGE on MARGIN SELECTION

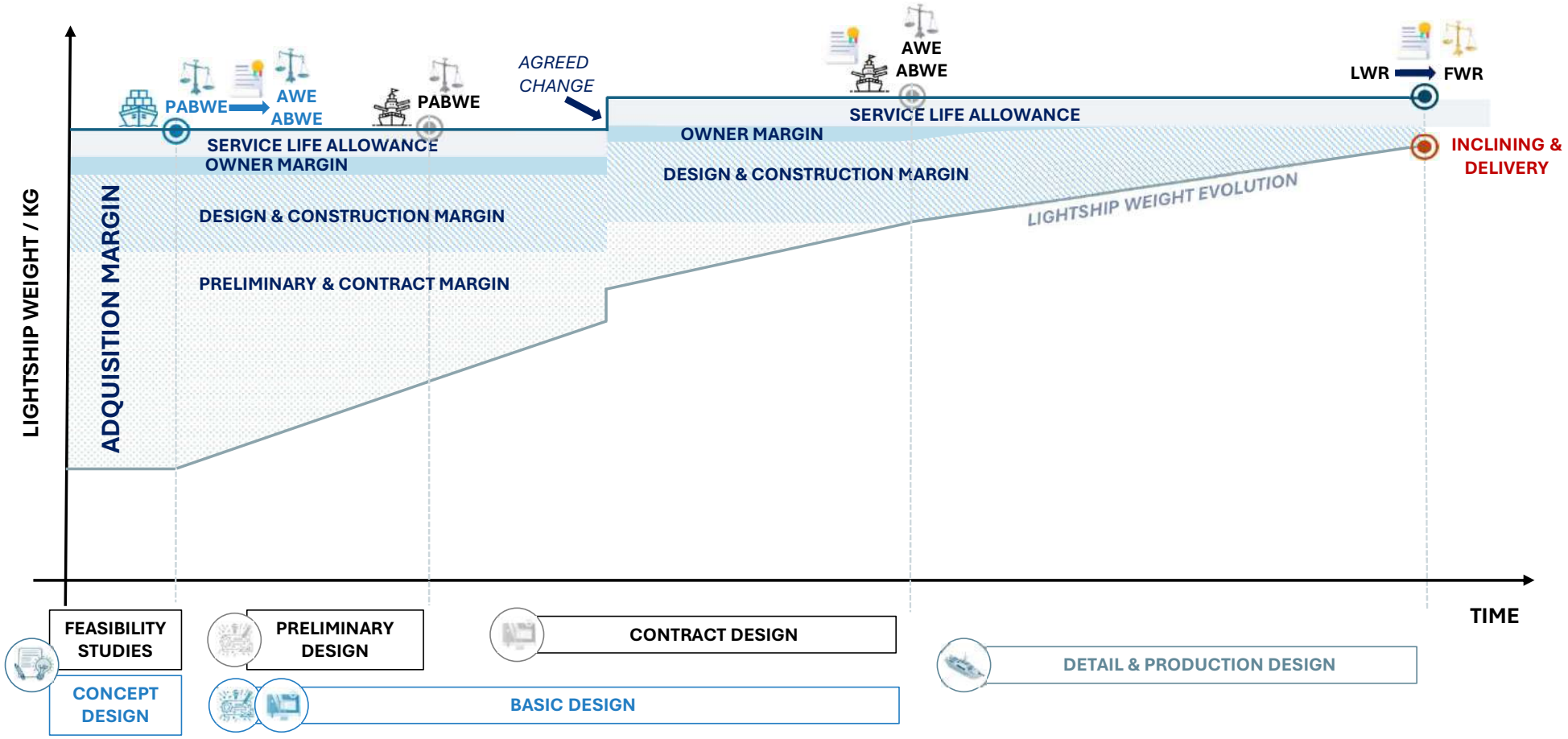
- *EXCESSIVE:* Higher costs!
- *INSUFFICIENT:* *Project non-compliace!*

DEFINE MARGIN

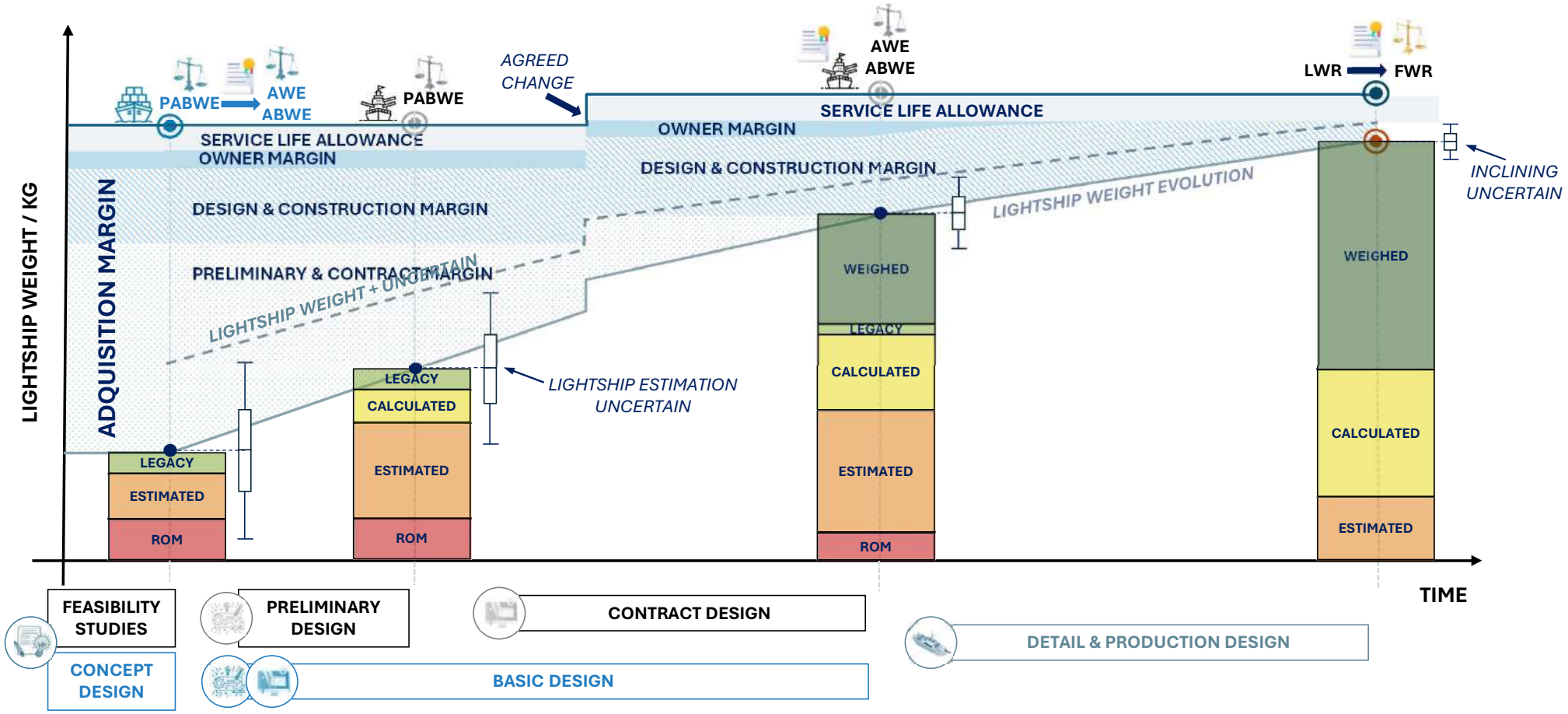
To ensure that the lightship weight → *It is achieved at delivery*



LIGHTSHIP WEIGHT CONTROL



LIGHTSHIP WEIGHT CONTROL



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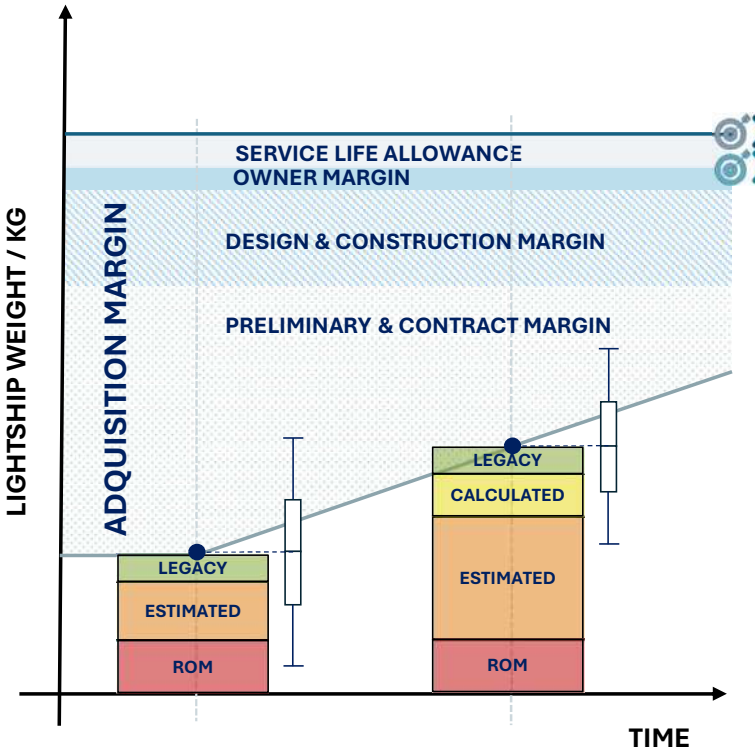


LWT at End of Life
LWT at Delivery

OWNER MARGIN
- Material provided by Owner

SLA MARGIN
- Ship alterations
- Repainting
- Equipment replacement

LWT at Delivery

MARGIN
WEIGHT
KG

LWT at End of Life

ADQUISITION MARGIN

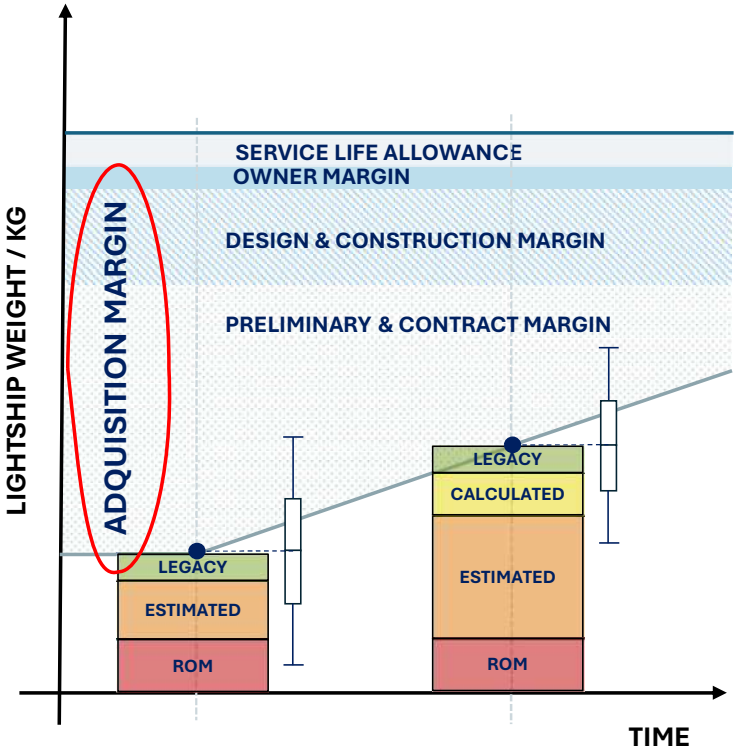
PRELIMINARY & CONTRACT

DESIGN& CONSTRUCTION
- Project development
- Bulk items
- Missing weights
- Uncertainties

Uncertainties generates margin!

*Controlling uncertainty is the **next step** on weight control*

LIGHTSHIP WEIGHT CONTROL



HOW TO DETERMINE ADQUISITION MARGIN?

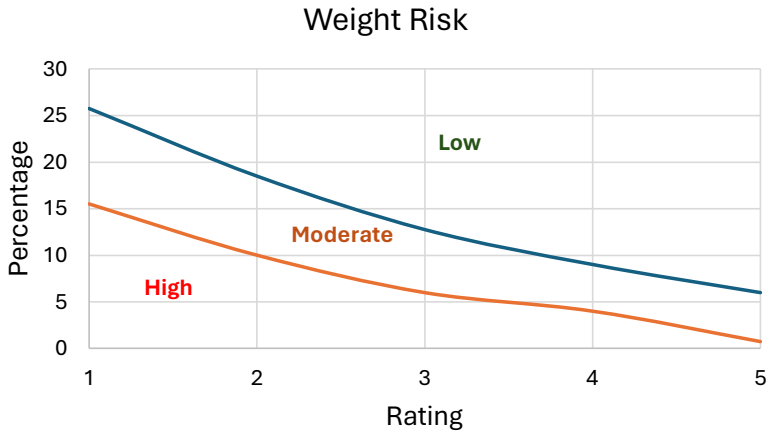
TRADITIONAL (SIMPLE) METHOD

ADQUISICION MARGIN BASED ON HISTORICAL PATTERNS

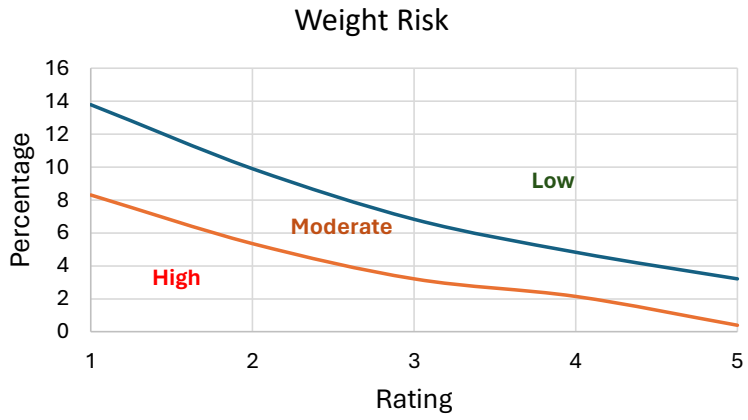
Considering the historical data of increasing lightship weight/KG

HISTORICAL PATTERNS

MILITARY SHIPS



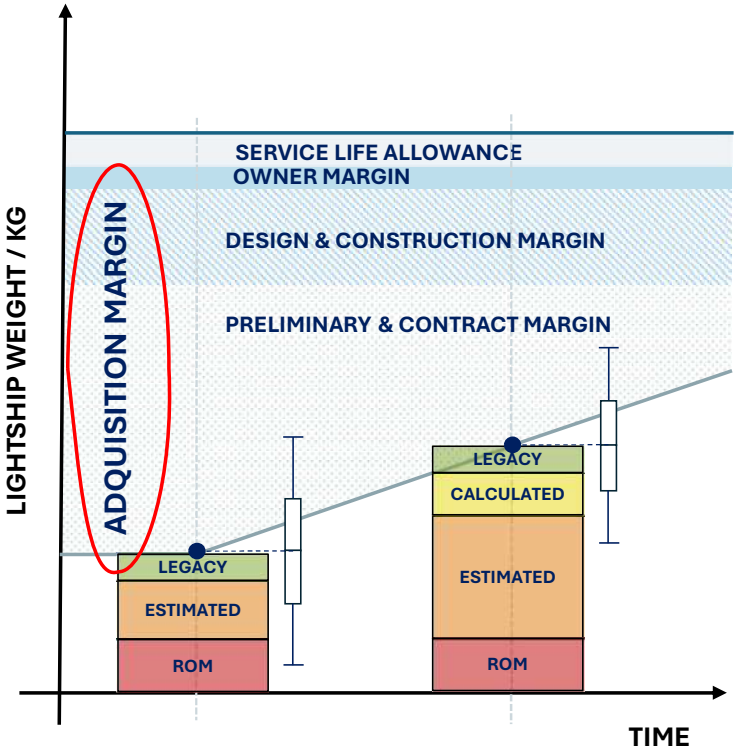
COMMERCIAL SHIPS



RATING → DESIGN CHARACTERIZATION (1-5)

RISK ASSESSMENT → RISK CONSEQUENCES

LIGHTSHIP WEIGHT CONTROL



HOW TO DETERMINE ADQUISITION MARGIN?

ALTERNATIVE (ADVANCED) METHOD

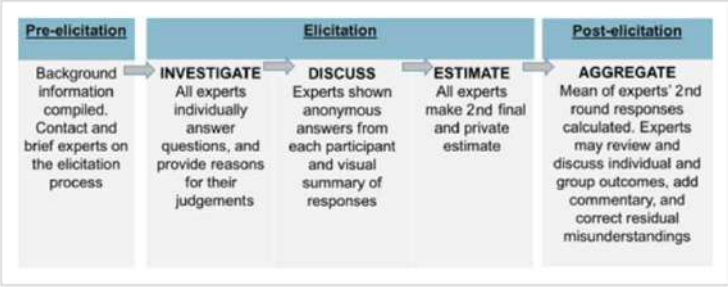
ALTERNATIVE MARGIN SELECTION

Experts based criteria of each discipline

ALTERNATIVE MARGIN SELECTION

	RISK SURVEY RESULTS							AVERAGE RISK
	A	B	C	D	E	F	G	
1 - HULL STRUCTURE	5	~~7~~	4	3	5	5	~~2~~	4,4
2 - PROPULSION PLANT	6	6	~~7~~	5	5	5	~~4~~	5,4
3 - ELECTRIC PLANT	5	~~6~~	5	6	5	6	4	5,4
4 - COMMAND & SURVEILLANCE	8	8	~~7~~	6	6	9	~~7~~	7,2
5 - AUXILIARY SYSTEMS	8	~~6~~	6	7	5	5	4	5,8
6 - OUTFIT & FURNISHINGS	6	6	~~5~~	4	5	6	4	5,2
7 - ARMAMENT	7	~~6~~	8	7	7	8	~~6~~	7

1. Lightweight breakdown into main disciplines (1…7)
2. Select several experts per discipline (A…G)
3. Perform experts survey:



4. Remove two extreme results (min/max) per discipline
5. Calculate average risk per discipline

RISK ASSESSMENT | Experts selected on each main discipline

ALTERNATIVE MARGIN SELECTION

ALTERNATIVE MARGIN SELECTION

Experts based criteria of each discipline

	RISK SURVEY RESULTS							AVERAGE RISK
	A	B	C	D	E	F	G	
1 - HULL STRUCTURE	5	~~7~~	4	3	5	5	~~2~~	4,4
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6 - OUTFIT & FURNISHINGS	6	6	~~5~~	4	5	6	4	5,2
7 - ARMAMENT	7	~~6~~	8	7	7	8	~~6~~	7

6. Use the average risk to calculate the margin for each discipline using the statistical bounds:

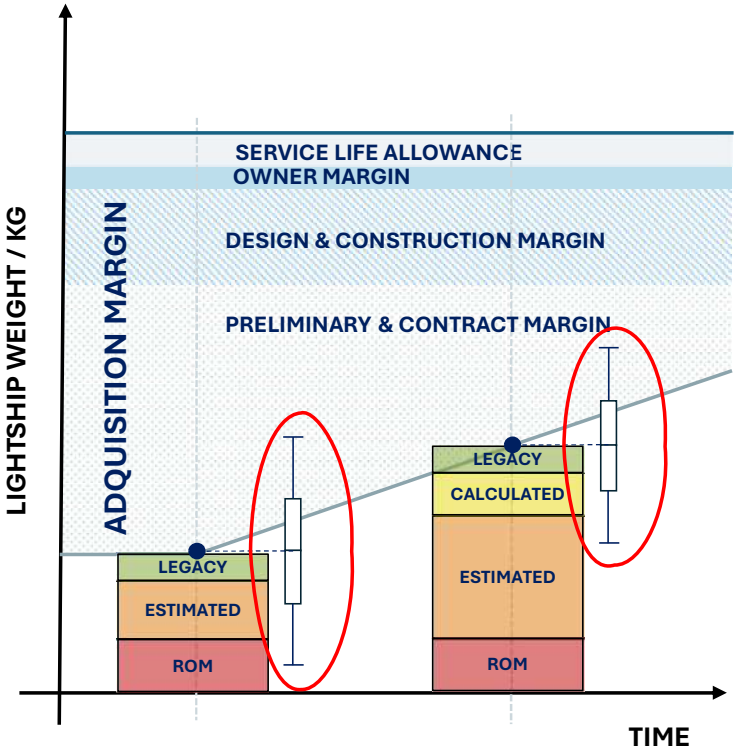
STATISTICAL BOUNDS VALUES FOR MARGIN				
	WEIGHT		KG	
	Min.	Max.	Min.	Max.
ADQUISITION MARGIN	6%	18%	5%	14%
PRELIMINARY & CONTRACT MARGIN	1%	8%	3%	8%
DESIGN & CONSTRUCTION MARGIN	5%	10%	2%	6%

$$\%W(1 \dots 7)_M = \left(\%Min. + \left(\frac{Risk(1 \dots 7)}{10} \right) * (\%Max. - \%Min.) \right)$$

7. Compound per discipline and overall margin.

RISK ASSESSMENT | Experts selected on each main discipline

LIGHTSHIP WEIGHT CONTROL



HOW TO DETERMINE UNCERTAIN?

NEXT STEP ON WEIGHT CONTROL

UNCERTAIN CONTROL WILL:

- ✓ *Generate confidence on the estimations*
- ✓ *Optimize weight control effort by focus on most important items*
- ✓ *Determine accurately and prematurely the risks of the project*
- ✓ *Check if the weight control progress correctly*

UNCERTAINTIES CALCULATION

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Weight breakdown will reduce uncertain

Divide et impera

Julio César

1. Breakdown by Weight group
2. Evaluate each group separately, look for uncertainty information.
3. Breakdown each weight group. Each system is subdivided into equipment, pipes, etc.

Example:

System: 100 ton +- 10 ton (10% uncertain)

- *Piping: 70 ton +- 4 ton (5,7% uncertain)*
- *Fittings: 10 ton +- 2 ton (20% uncertain)*
- *Equipment: 20 ton +- 4 ton (20% uncertain)*

Total= 100 ton +-6 ton (6% uncertain)

$$\sigma_{sum} = \sqrt{\sigma_1{}^2 + \sigma_2{}^2 + \cdots}$$

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UNCERTAINTIES CALCULATION

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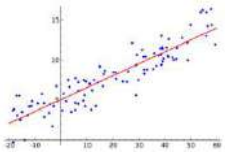
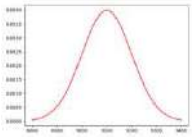


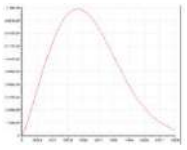
Calculation **by sampling or data literature**

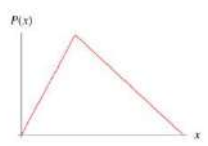
Values from quality control

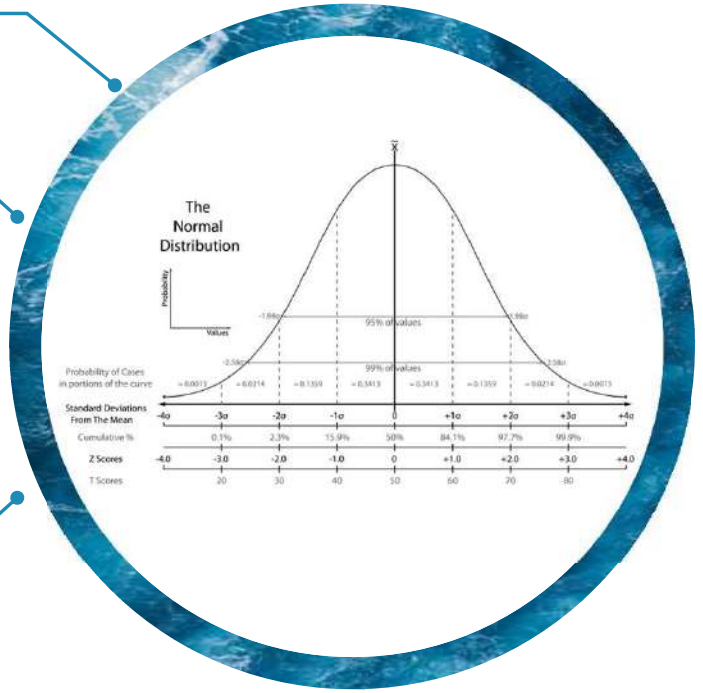
WEIGHED
LEGACY
CALCULATED
ESTIMATED
ROM

Weight maturity status









$$\sum_{i=0}^{n} X_i$$

CENTRAL LIMIT THEOREM

In probability theory, the sum of a large number of distributions with non-zero variance will converge to a standard normal distribution. This holds even if the original variables themselves are not normally distributed.

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WEIGHT CONTROL BASED ON UNCERTAINTIES ASSESSMENT

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MONTECARLO ANALYSIS SPREADSHEET

Item ID	Description	Number of Units	Unit pcs m m^2 m^3 liter	Specific weight kg kg/m kg/m2 kg/m3 kg/liter	Weight (kg)	LCG (m)	TCG SB(+) PS(-) (m)	VCG (m)	Stage ROM Estimated Calculated Legancy Weighed	Date DD/MM/YYYY	Uncertain Ranking Weight	Uncertain Ranking KG
---	Original Lightship	1	pcs	3182996	3182996	39.045	-0.030	7.688	Weighed	06/03/2024	0.6%	0.5%
	Methanol Tanks Modification (new stores)											
100	Corrugated bulkheads openings	1	pcs	-200	-200	11.400	0.000	5.900	Estimated	06/03/2024	6.5%	2.5%
600	False floor installation	97.96	m2	60	5877.6	11.100	0.000	3.700	Estimated	06/03/2024	10.0%	3.7%
600	Side stairs	2	pcs	60	120	10.720	0.000	4.095	Estimated	06/03/2024	2.0%	0.8%
600	Main stairs	1	pcs	150	150	13.480	-2.900	6.700	Calculated	06/03/2024	1.5%	0.5%
600	Shelves	97.96	m2	5	489.8	11.100	0.000	4.700	Estimated	06/03/2024	5.0%	3.0%
500	New ventilation ducts	1	pcs	300	300	13.500	0.000	7.000	Calculated	06/03/2024	0.5%	0.3%
300	Lighting and electrical	1	pcs	200	200	11.100	0.000	7.000	Estimated	06/03/2024	2.0%	0.8%
600	Safety (piping and fire equipment)	1	pcs	200	200	15.000	0.000	5.000	Calculated	06/03/2024	0.8%	0.3%
500	Remove methanol piping	1	pcs	-5000	-5000	18.000	0.000	2.000	Weighed	06/03/2024	0.0%	0.0%

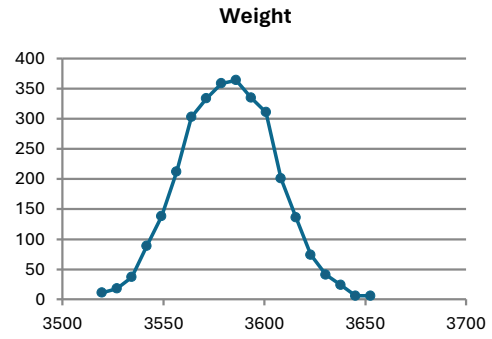
CONFIDENCE LEVEL → SAMPLE SIZE

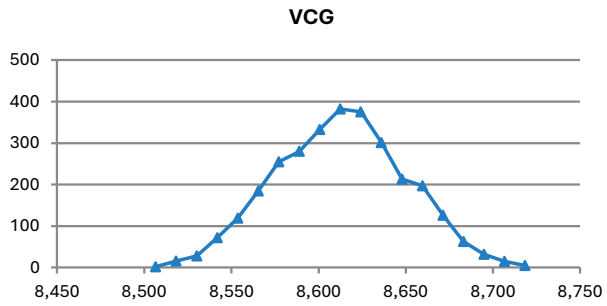
NORMAL DISTRIBUTION STATISTICS

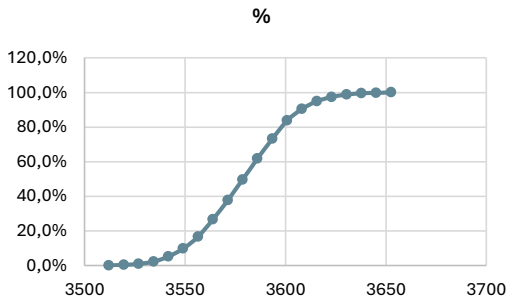
Sigma	1.64	Confidence level	95.0%

	Weight (ton)	LCG (m)	TCG SB(+) PS(-) (m)	VCG (m)
Weight (95%)	3615.6	35.696 (+-0.204)	-0.076 (+-0.009)	8.668

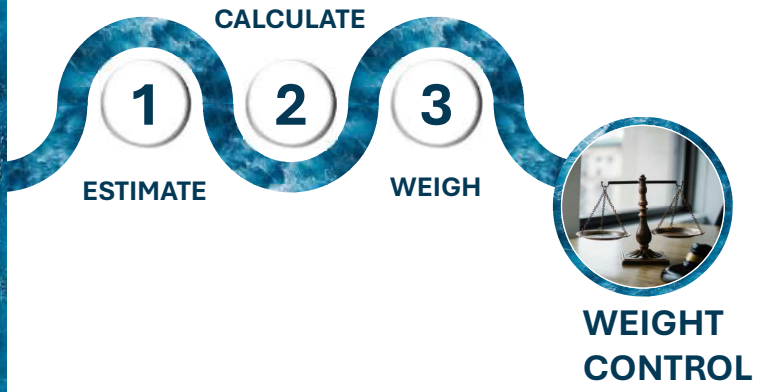
RESULTS

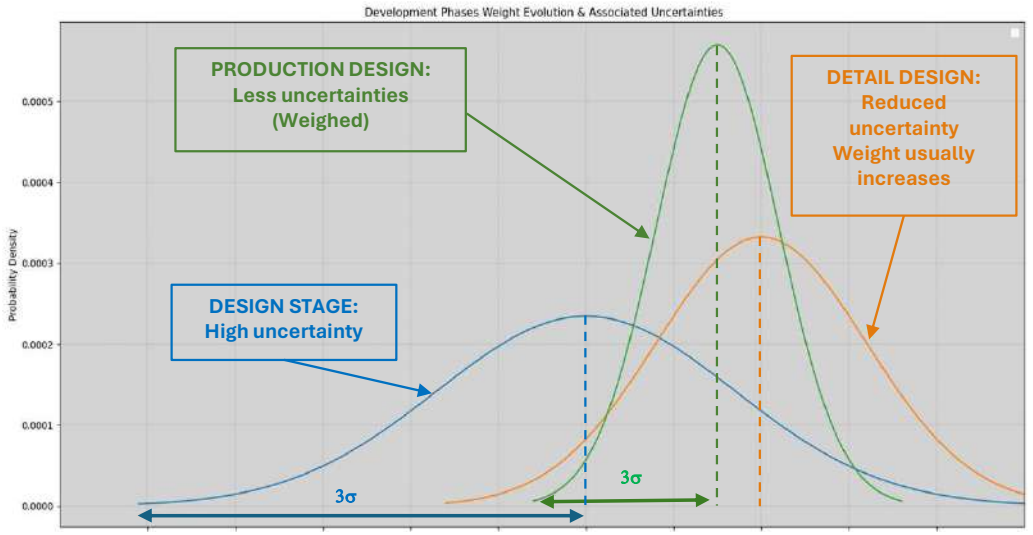


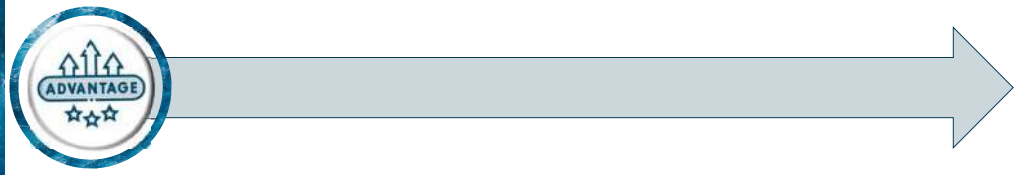




UNCERTAIN as RISK MEASURE







- Allows risk monitoring (margin monitoring)
- Makes it easy to focus on the weights with the greatest uncertainty

IDENTIFYING OPPORTUNITIES

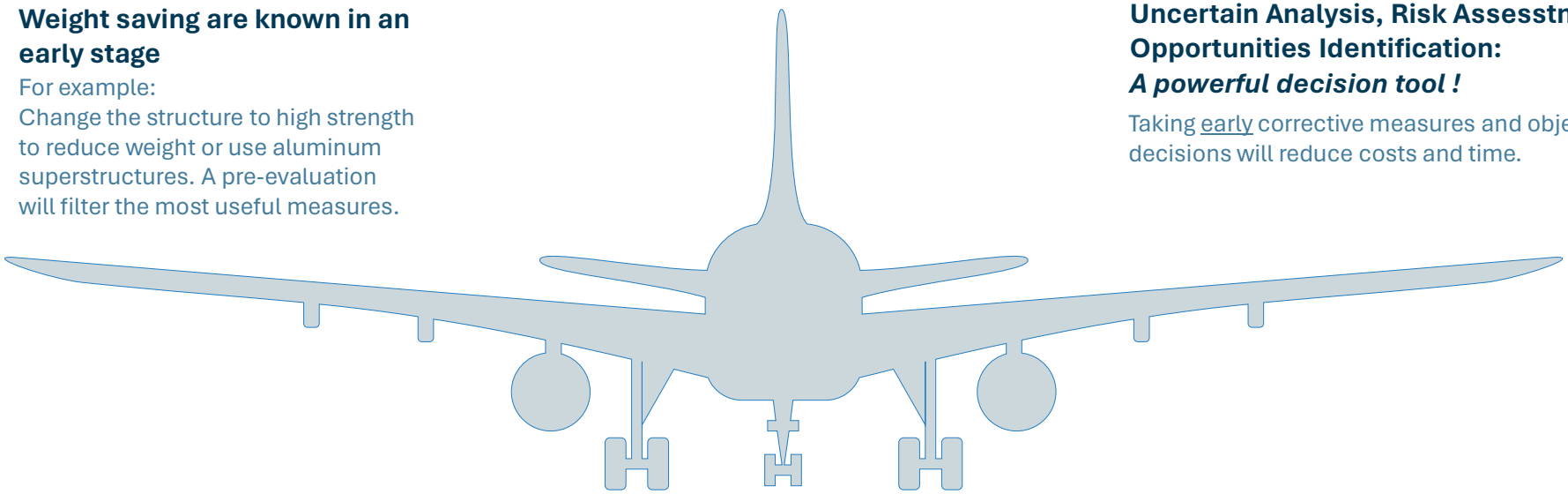
AERONAUTICAL SECTOR

MARINE SECTOR

Experts in each area of the design, identifying viable weight saving opportunities and their uncertainties

Weight saving are known in an early stage

For example:
Change the structure to high strength to reduce weight or use aluminum superstructures. A pre-evaluation will filter the most useful measures.



Uncertain Analysis, Risk Assesstment & Opportunities Identification:
A powerful decision tool !

Taking early corrective measures and objective decisions will reduce costs and time.

María Dolores Fernández Ballesteros

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***Acknowledgements*:**

SAWE Central European Chapter

https://sawe.org/chapters/centraleurope/

Thank you for your attention!