Optimising the DOLPHIN Mission: A Feasibility Study using Cost Engineering Principles

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Image by NASA, James Webb

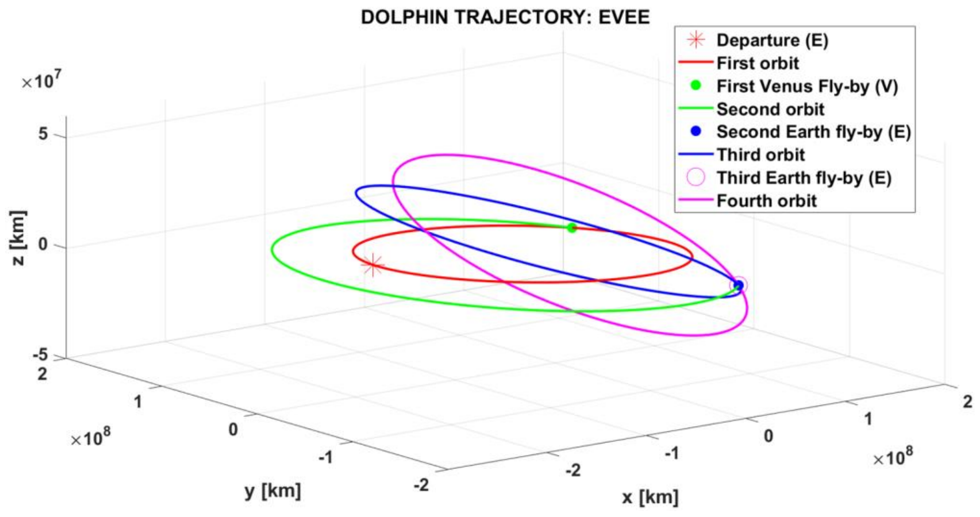
Introduction

Study interstellar dust and particles

Launch in 2031 (or 2047) during the solar cycle minimum

High inclination through EVEE flyby

Collaboration with ETH Zurich



Computed by Dr Andrea Bellome

Motivation

ESA F-Class

- Submitted to F2 call in 2022
- Launched in 2030-31
- CaC < **175 M€**
- Wet mass: 750 kg
- Dry mass: 450-500 kg
- TRL of 5-6
- Vega C or Ariane launcher

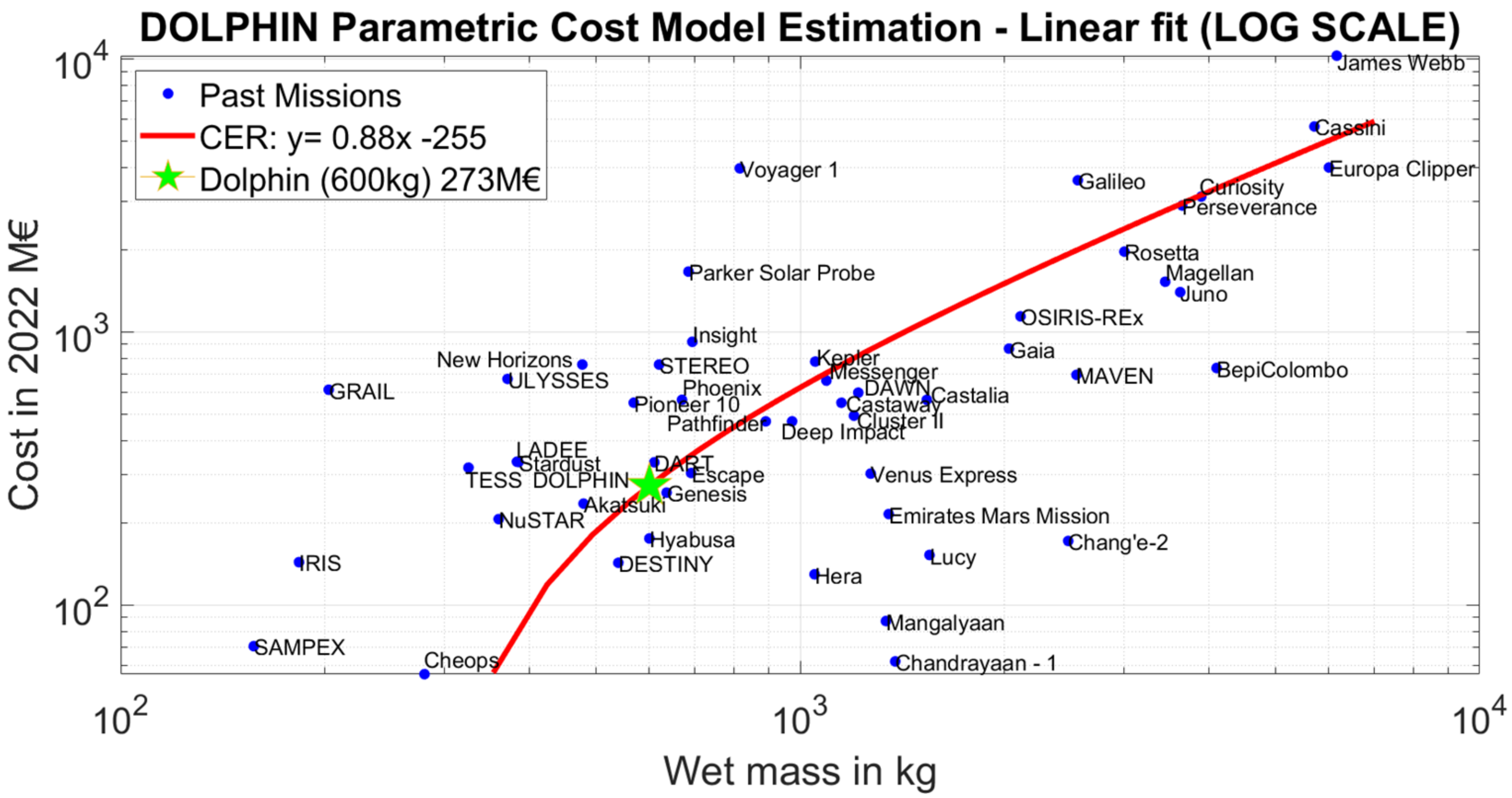
Reasons for Rejection

Challenges posed by interplanetary transfer

Predicted high cost of spacecraft design

175 M€

Preliminary Estimation - Cost

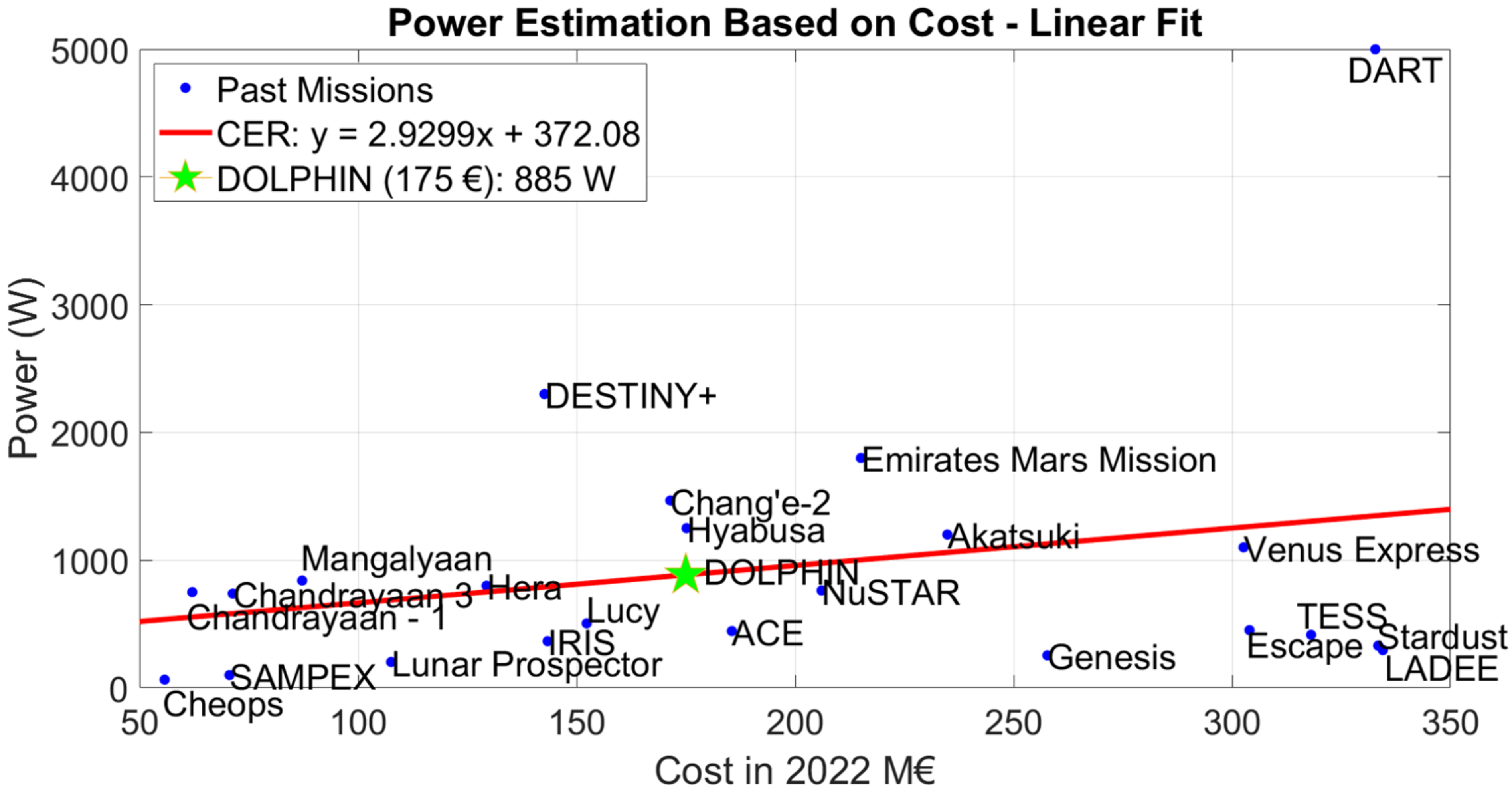


Dry Mass:
150-3000 kg

Wet Mass < 6000 kg

€273 million

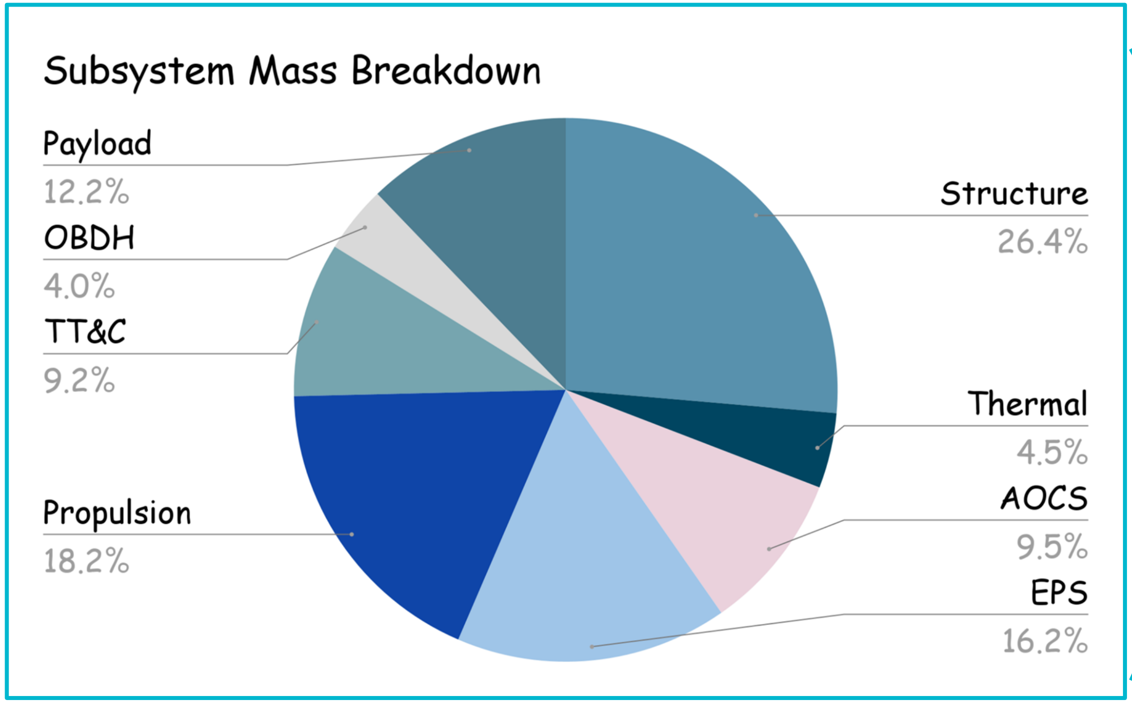
Preliminary Estimation - Power



885 W

Preliminary Estimation - Mass & Cost Models

Dry mass 400 kg



SSCM

- Parametric cost model
- Based on 53 satellites, most smaller than 100 kg
- Does not distinguish between recurring and non-recurring costs

€ 214 million

USCM8

- Parametric cost model
- Based on 44 communication satellites, in Earth orbit
- Separates between recurring and non-recurring costs

€ 253 million

Objectives

Selection of Components through Trade-Off

Redefine Mass Budget

Cost Estimation for DOLPHIN

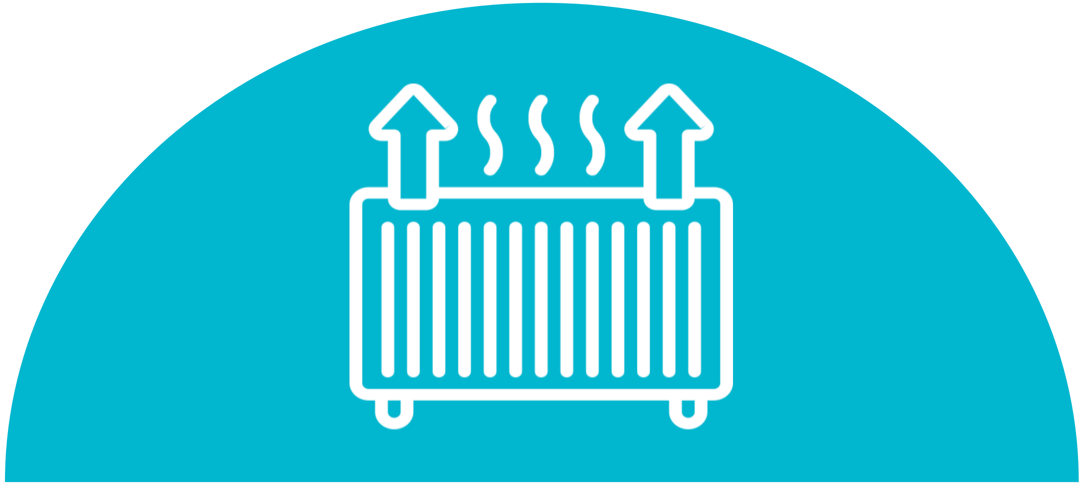
Descoping Options for Cost Reduction

Determine the feasibility of launching under the ESA F-Class constraints!

Subsystem Design & Trade Off Study

Thermal Control Subsystem

Payload Temperature ϵ [-15, +40] °C



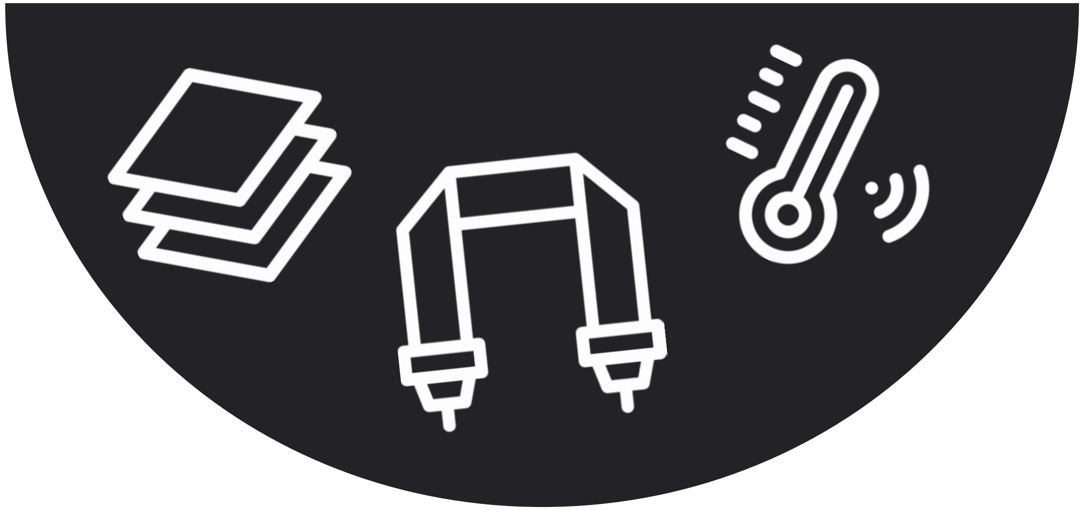
Radiator sized for Venus Fly-by

Hypothesis:

- Sun flux at Venus
- T < 30°C
- Dissipated P = 50 W
  → COTS **HiPer Radiator** (Airbus) selected

Passive & active components from *Comet Interceptor*

- MLI
- Thermal fillers
- Thermal strap
- Thermal washers
- Thermistors
- Heaters



Telemetry, Tracking & Command

X Band
Data rate: 70 Mbit/day + housekeeping

Deep Space 1

12 W Power Amplifier

0.25 m diameter HGA

Link Margin: - 8.3 dB

Comet Interceptor

65 W Power Amplifier

0.9 m diameter HGA

Link Margin: 10 dB

17 W Power Amplifier

0.9 m diameter HGA

Link Margin: 4.4 dB

Electrical Power Subsystem

900 W

Cheapest

Si

High η Si

Lightest

GaAs Single

GaAs Dual

Smallest

GaAs Triple

Lowest cost over specific BOL power
(€ × kg/W)

kg -41 %

€ -80 %

+78 %

NCO
- Juno
- Phoenix
- Curiosity

LCO
- Kepler
- Aquarius

Lowest cost over specific energy
(€ × kg/Wh)

SA + Battery = 80% of EPS mass

PDU

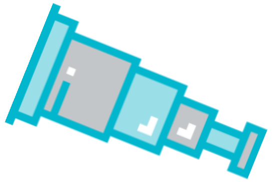
AOCS Subsystem

3 axis stabilised
Pointing Accuracy = 0.1° - 1°
SRP = 4×10^{-6} N m

2x Sun Sensors

4x Reaction Wheels

4x Gyroscopes



3x Star Trackers

12x 1 N Thrusters

OnBoard Data Handling Subsystem

70 Mbit/day
95 Gbit storage

OBC Airbus
ICDE-NG +
SSMM Nemo 2

VS

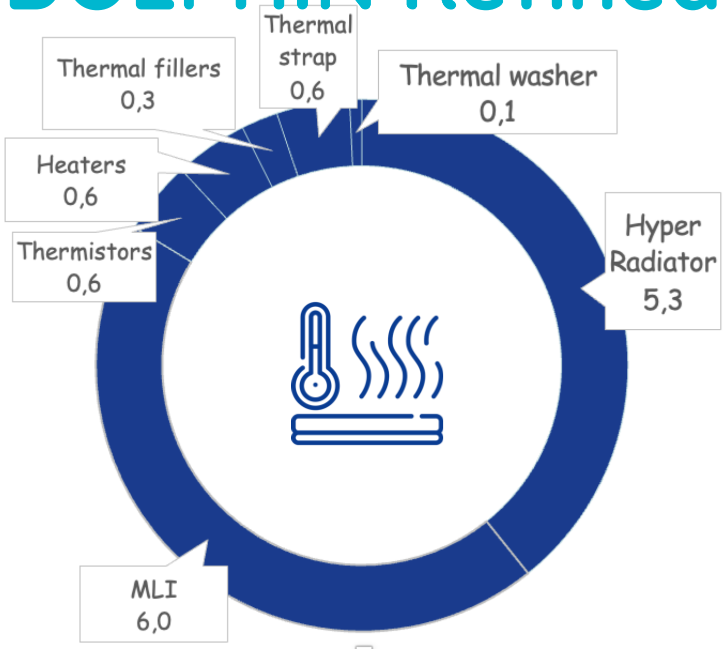
Thales Alenia
Space
IPAC OBC

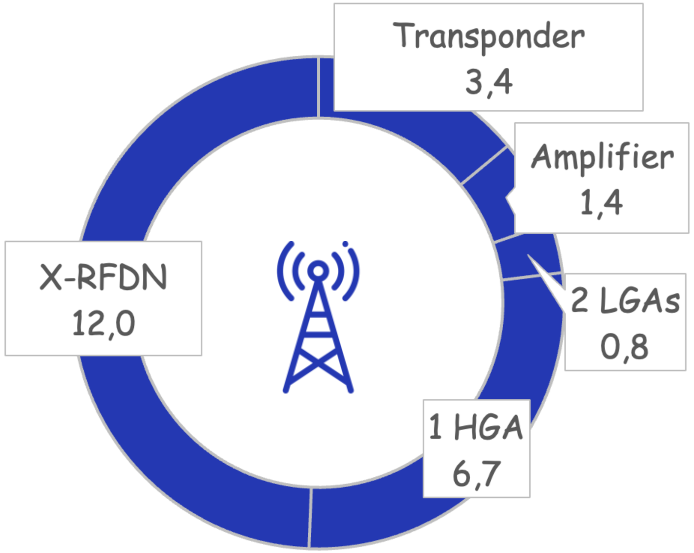
Lower power/mass (W/kg)

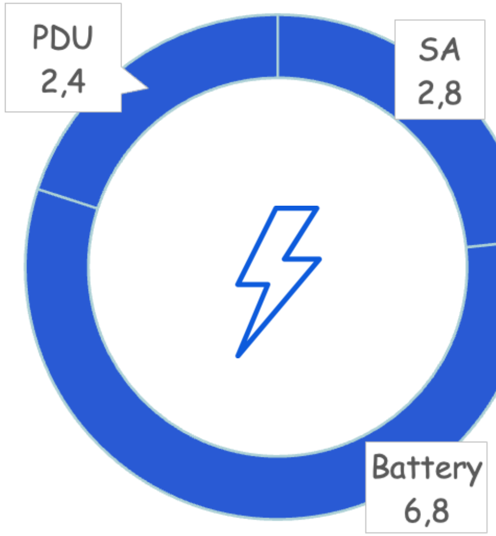
kg +24%

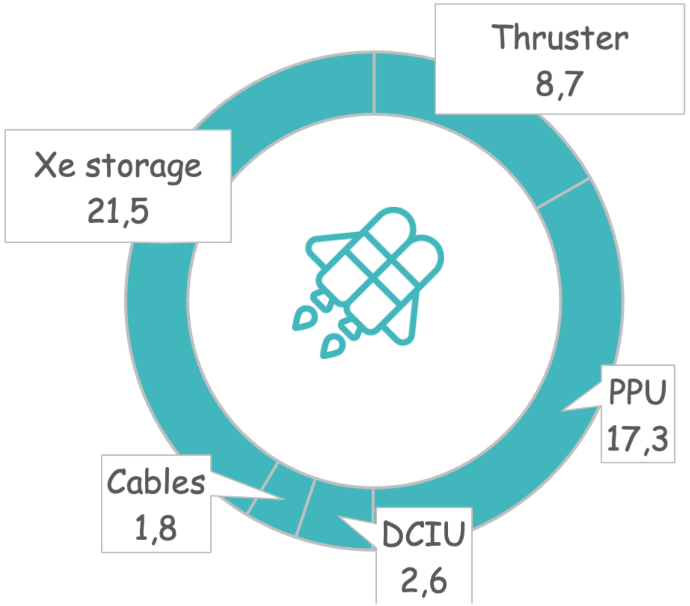
W -35%

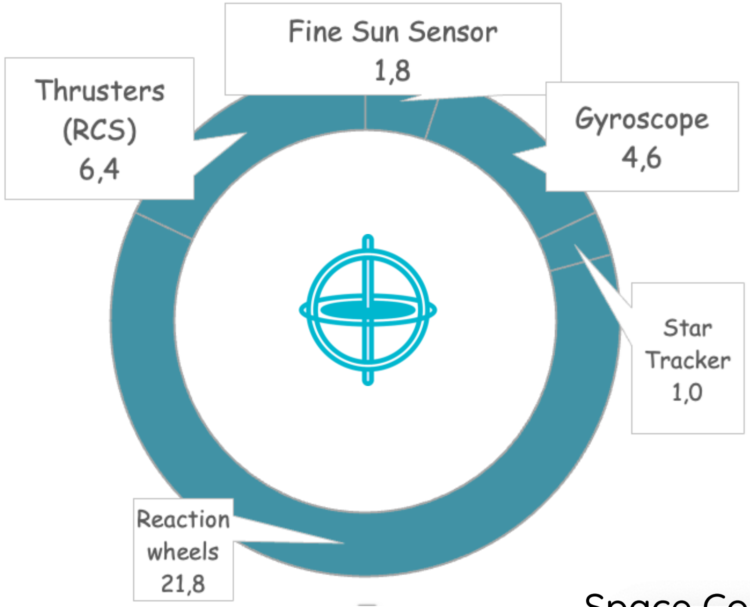
DOLPHIN Refined Mass Budget

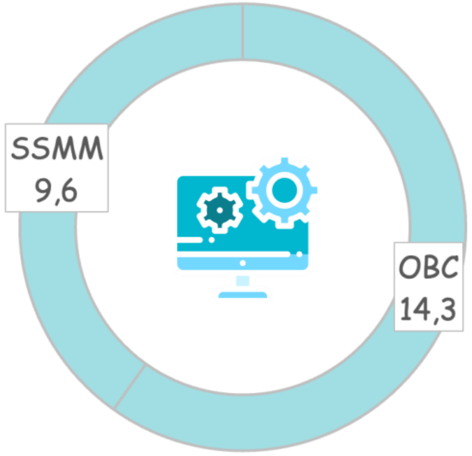








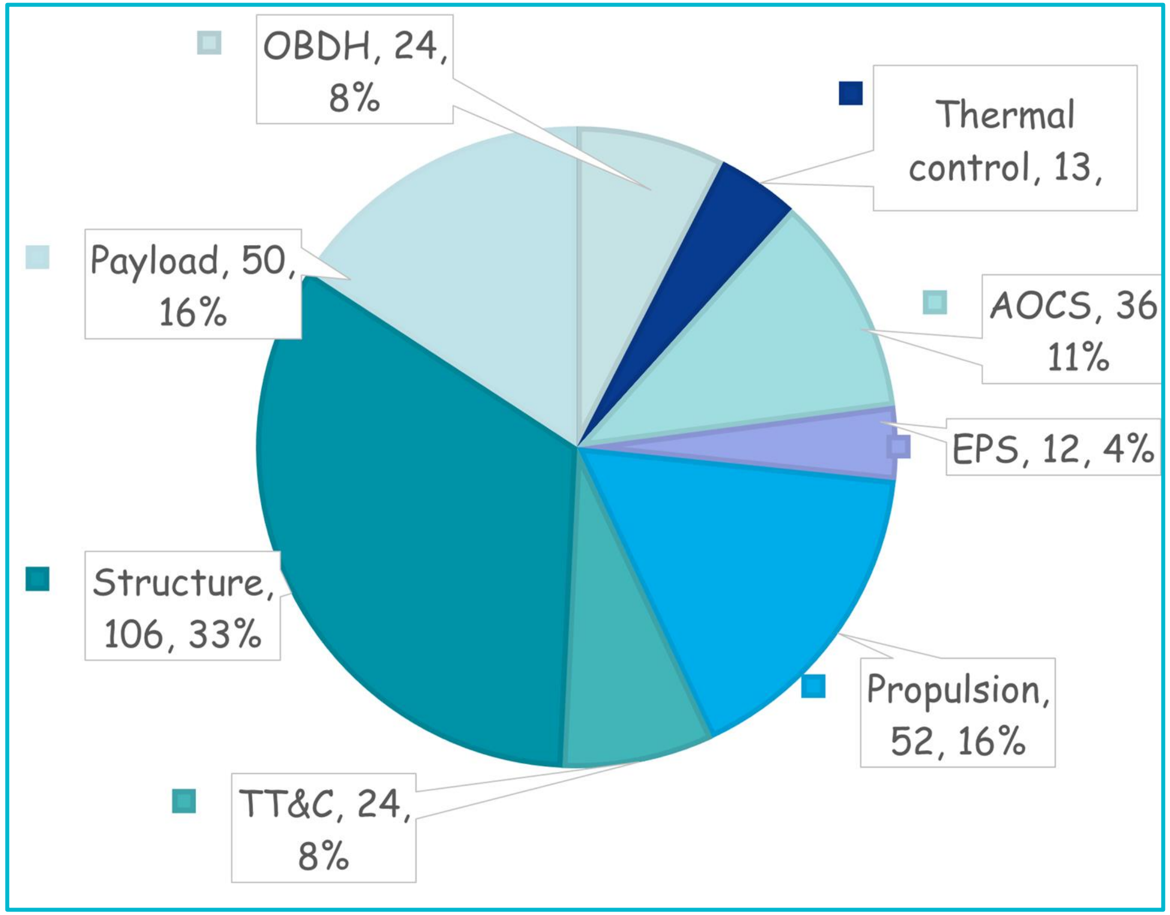




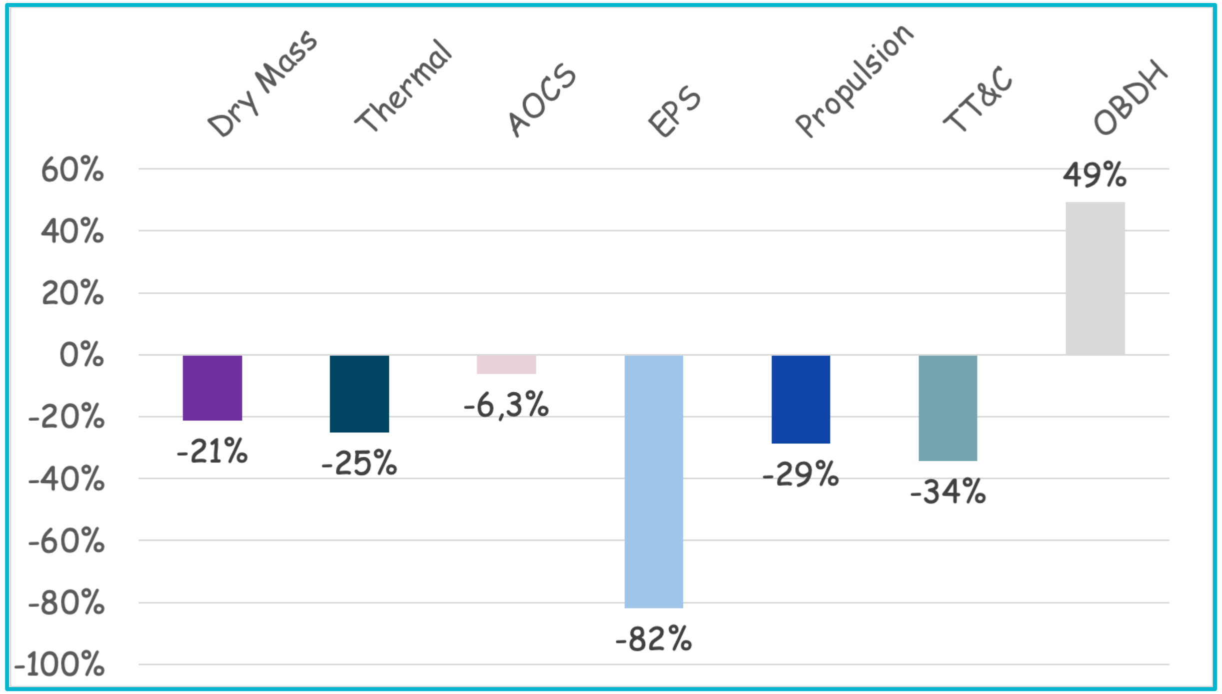
DOLPHIN Refined Mass Budget

Selection of Components through Trade-Off

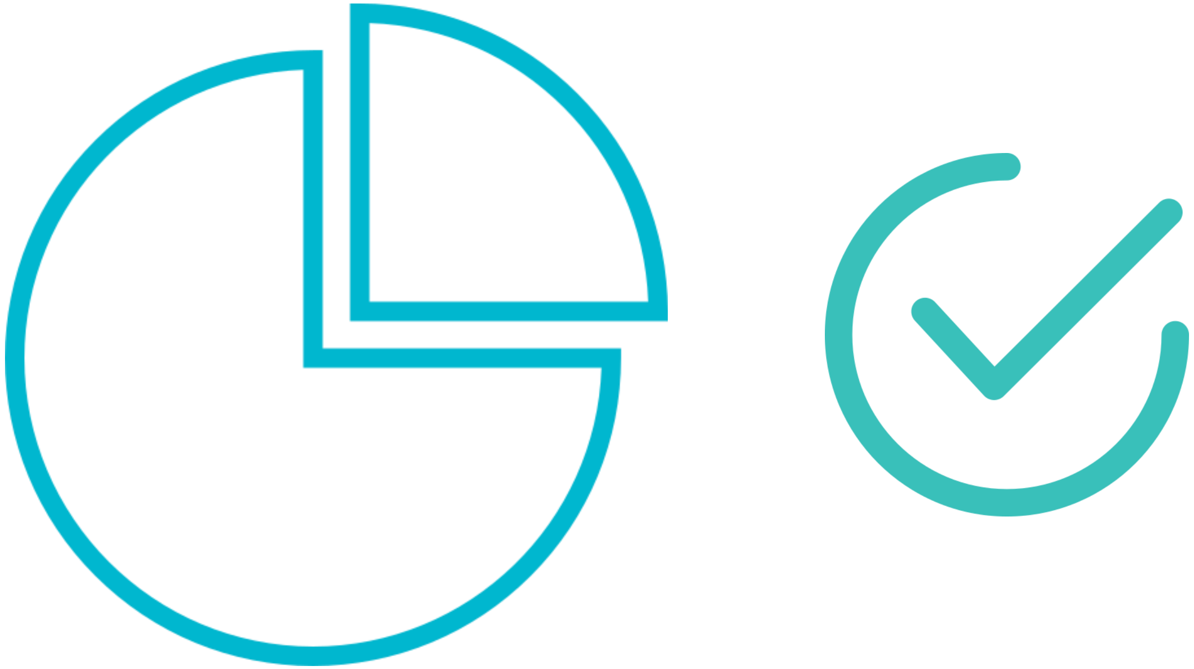
Subsystem Mass Distribution % of tot dry mass (317 kg)



Mass % reduction from 1st to 2nd iteration



Total dry mass with system margin: 397 kg



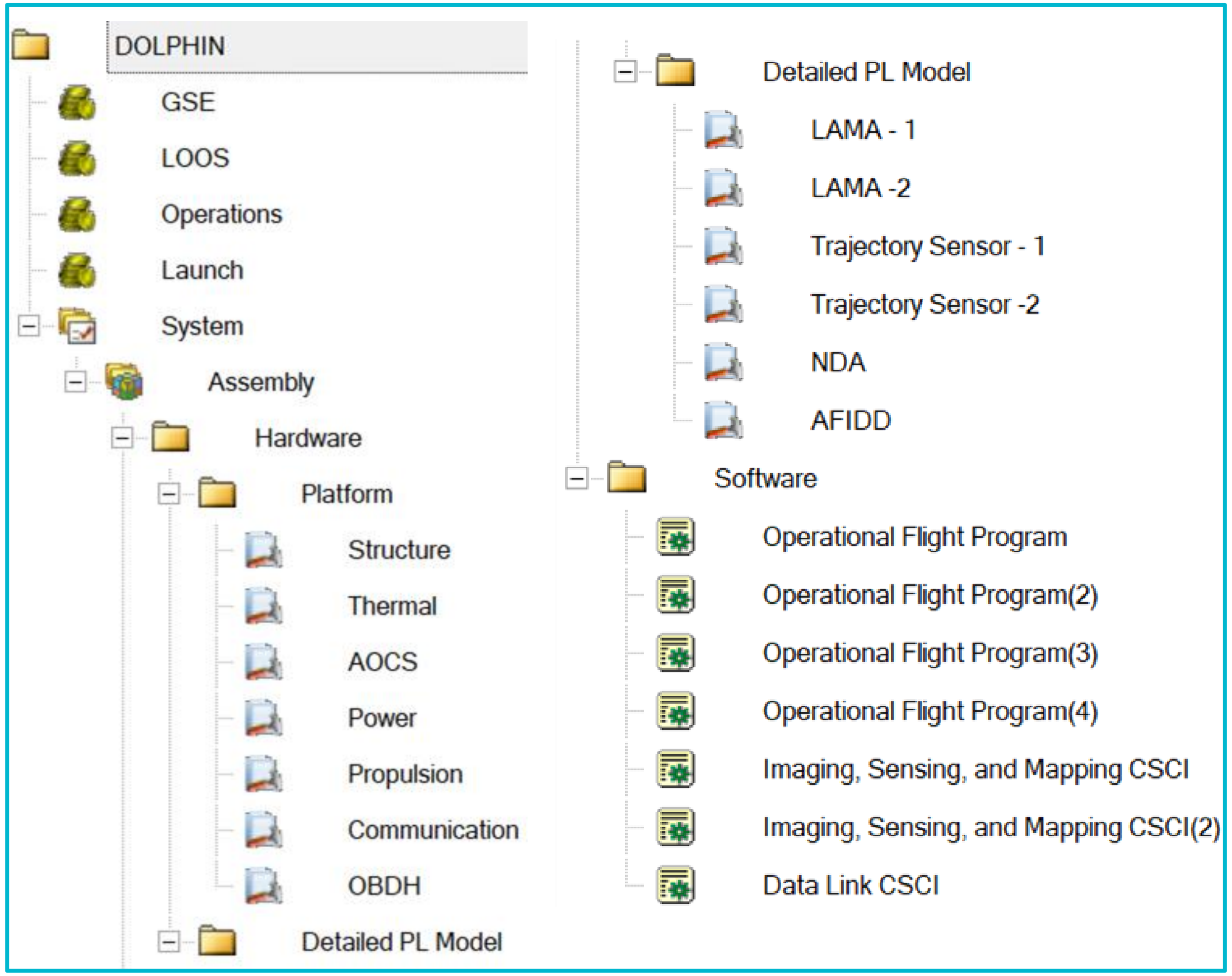
Redefine Mass Budget

Platform + Payload	86 M€
IA&T Program GSE LOOS	30M€
Software	21 M€
Launch	9.3 M€
Operations	25M€
	171 M€

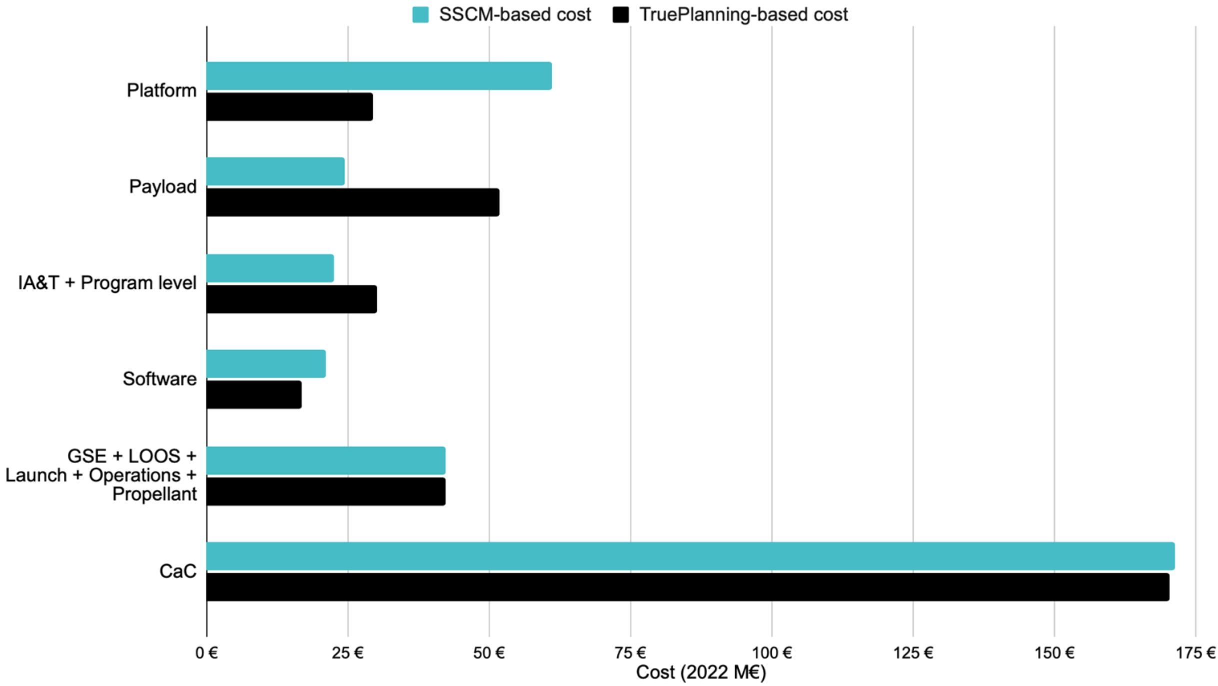
Refinement of Cost Budget (SSCM)

DOLPHIN TruePlanning Model

Final mission cost model



CaC comparison

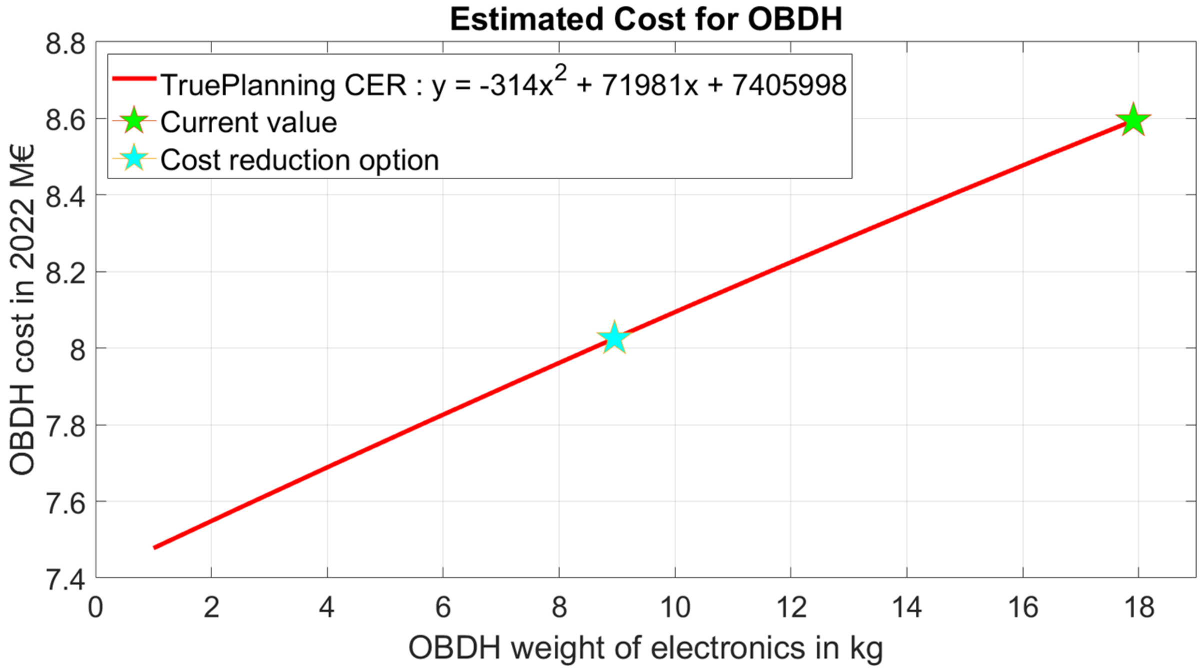


TruePlanning CaC 170 M€

SSCM vs TruePlanning

Cost Estimation for DOLPHIN

Descoping: TruePlanning



50% OBDH electronics mass reduction

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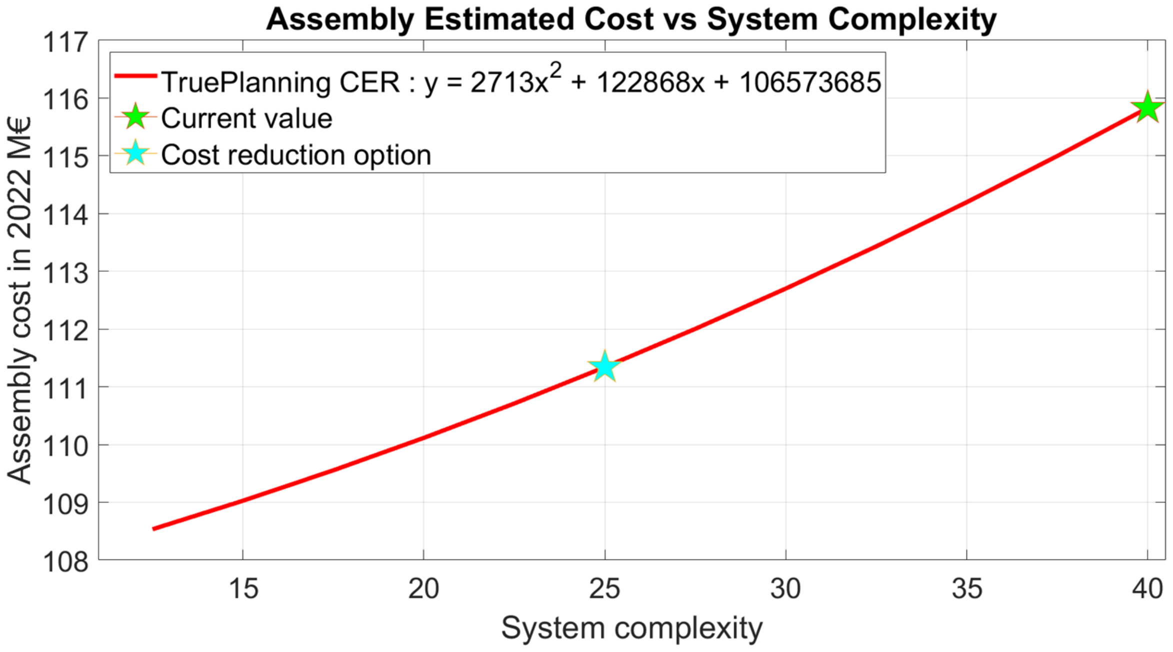
-7% OBDH cost ≅600 k€



Moderately complex → Familiar

↓

- 4% Assembly cost ≅4.5 M€

Descoping

Descoping Options for Cost Reduction

Conclusion

- Selection of Components through Trade-Off
- Redefine Mass Budget
- Cost Estimation for DOLPHIN
- Descoping Options for Cost Reduction

DOLPHIN fulfills the ESA F-Class cost constraints!

Thank You!