Small Satellite Reliability: A decade in review

35th Annual Small Satellite Conference

June 2021

Raja Pandi Perumal
University of Luxembourg

Holger Voos
University of Luxembourg

Hubert Moser
LuxSpace Sarl

Florio Dalla Vedova
LuxSpace Sarl

Introduction
Data Collection
Data Analysis
Results
Conclusion

Introduction

- Small satellite Era
- Unique advantages of small satellites
  - lesser design time
  - mass producibility
- Cost reduction
  - COTS components

- Consequently Small satellites
  - Low reliability
- Understanding the on-orbit reliability of satellites
- Goal of this paper

  investigate the reliability of small satellites launched over the last three decades.

Data Collection

Data Analysis

Results

Conclusion

- The dataset - on-orbit failure data of satellites
  - from the Seradata SpaceTrak database.

- Small satellites
  - Weight - 40-500 kg
  - launched between 1990-2019 (in last 3 decades)

- Collected data
  - launch date
  - failure date, when failure
  - censor date, when no failure
  - mission group
  - orbit inclination
  - equipment at fault.

- Censoring
  - when the satellite is in operation by the end of the observation window
  - if a satellite is turned off before it failed.

Introduction

Data Collection

Data Analysis

Results

Conclusion

Non-Parametric Analysis

- Kaplan Meier Estimator

Parametric Analysis

- Weibull distribution
  - Graphical method (GM)
  - Maximum Likelihood Estimate (MLE)

Approach

- Collective Analysis
- Categorized Analysis

Introduction

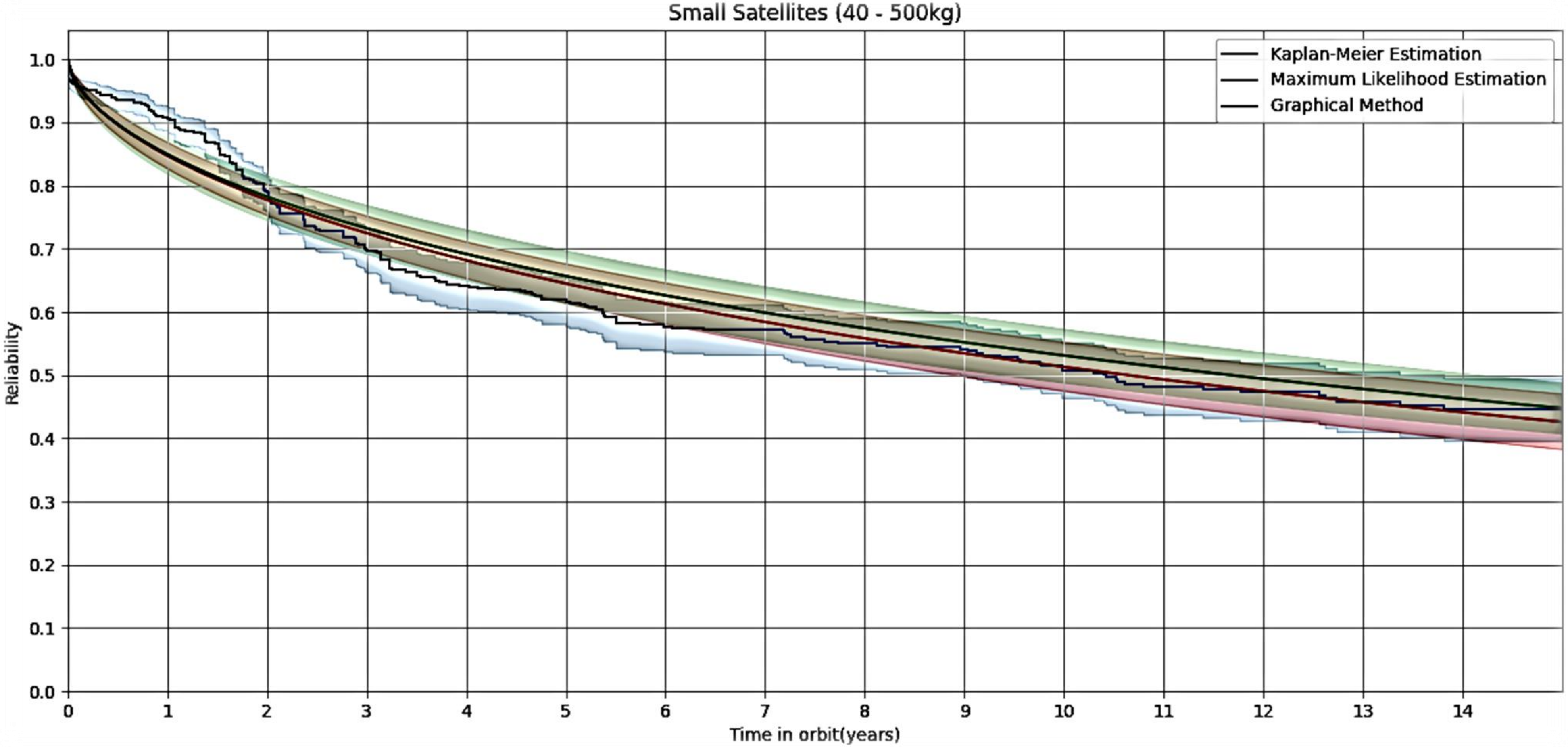
Data Collection

Data Analysis

Results

Collective Reliability

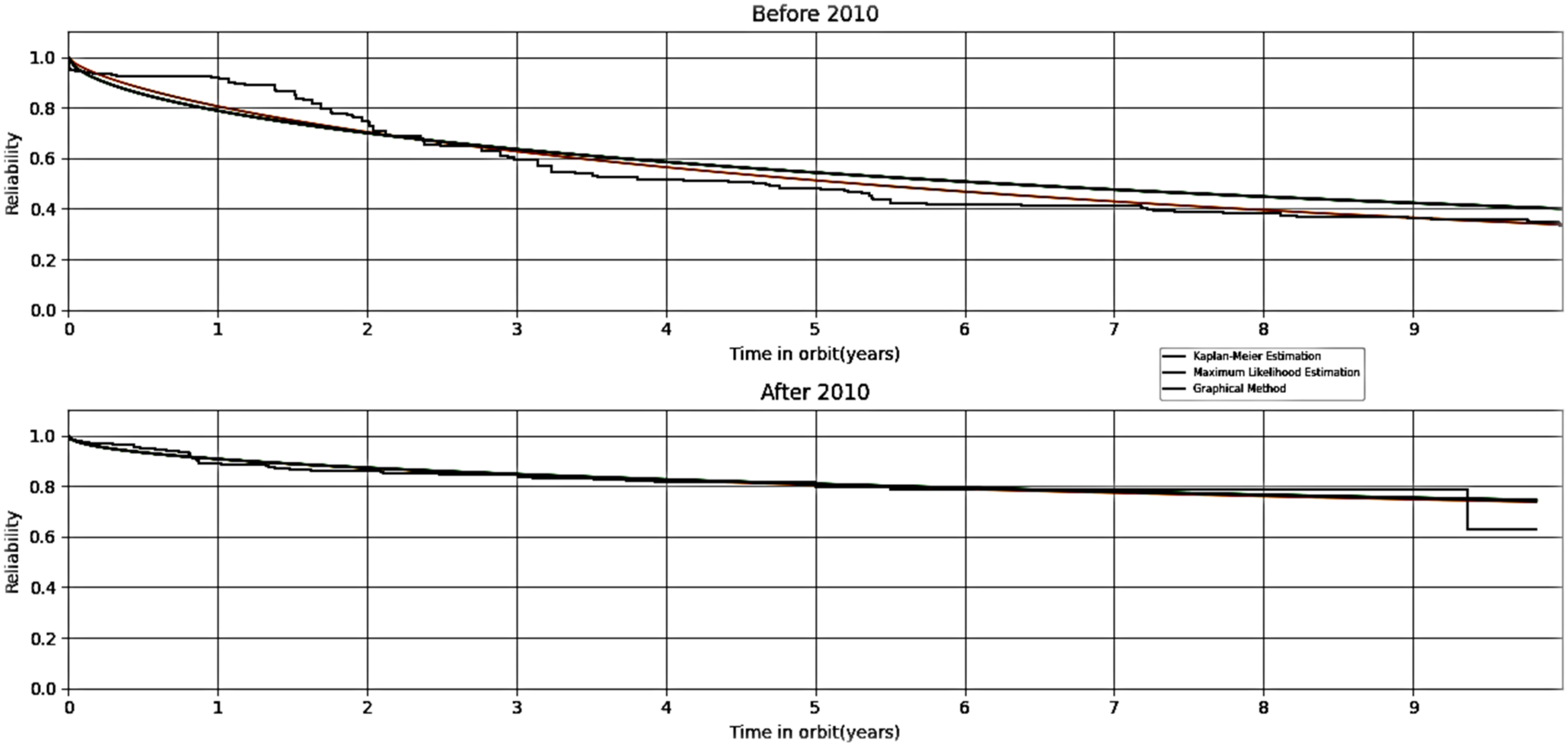
	Graphical - Method		MLE	
	α [years]	β	α [years]	β
Small Satellites	21.7553	0.5894	19.4949	0.6060



Conclusion

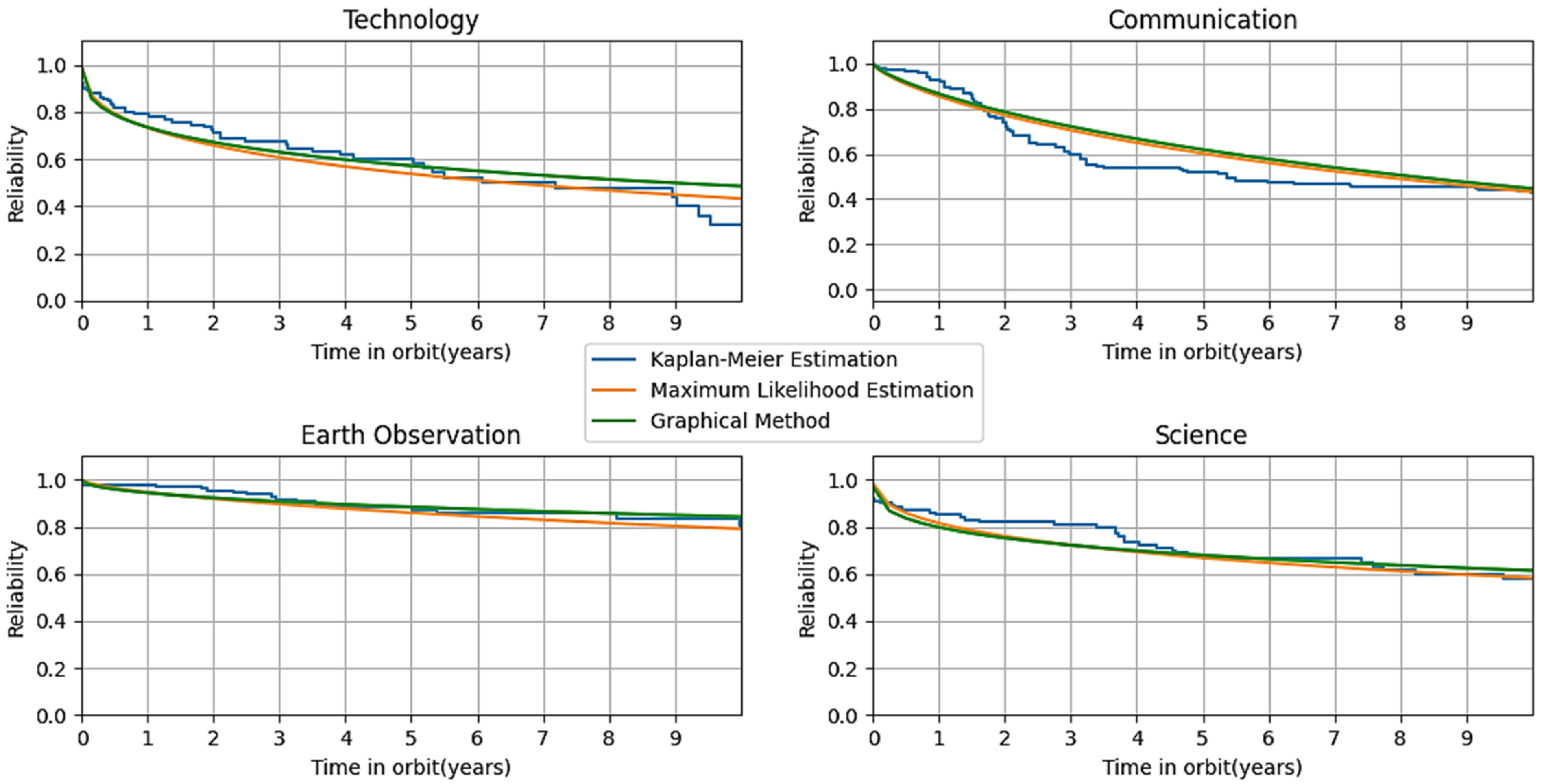
Reliability at different decades

Year	Graphical - Method		MLE	
	α [years]	β	α [years]	β
1990-2009	11.6442	0.5842	8.8792	0.7009
2010-2019	122.7151	0.4840	107.9955	0.4964

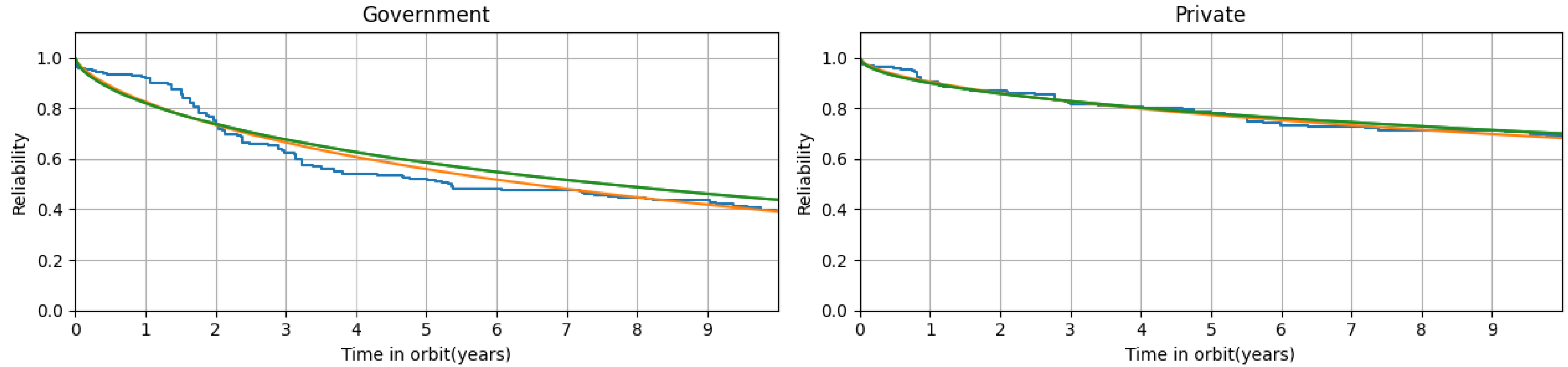


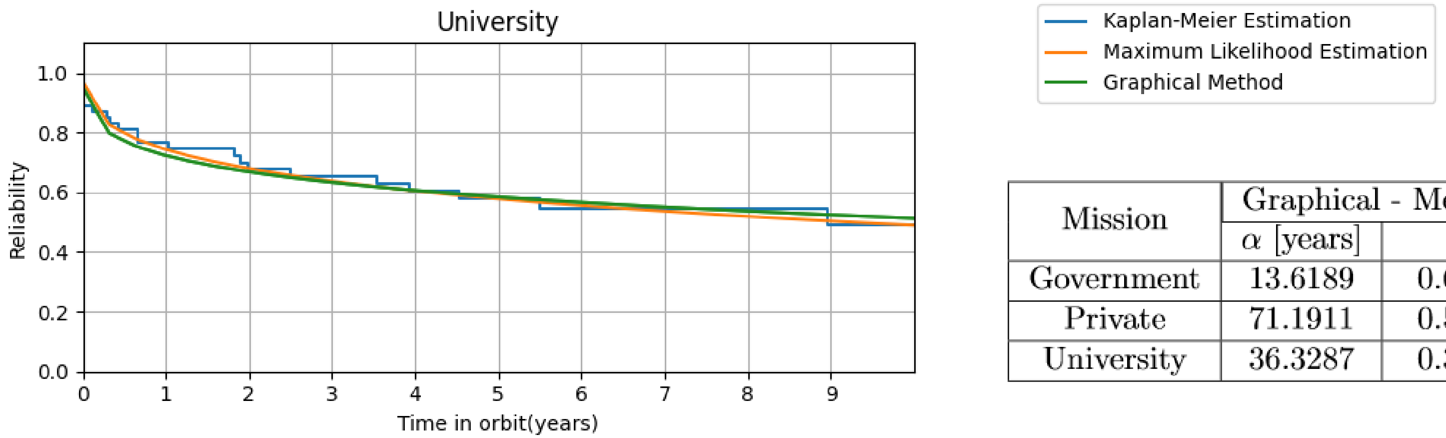
Reliability for different mission types

Mission	Graphical - Method		MLE	
	α [years]	β	α [years]	β
Technology	23.9288	0.3706	15.0166	0.4316
Communication	13.2987	0.7507	12.6880	0.7294
Earth Observation	412.6474	0.4739	99.7970	0.6310
Science	86.1004	0.3343	43.2374	0.4217



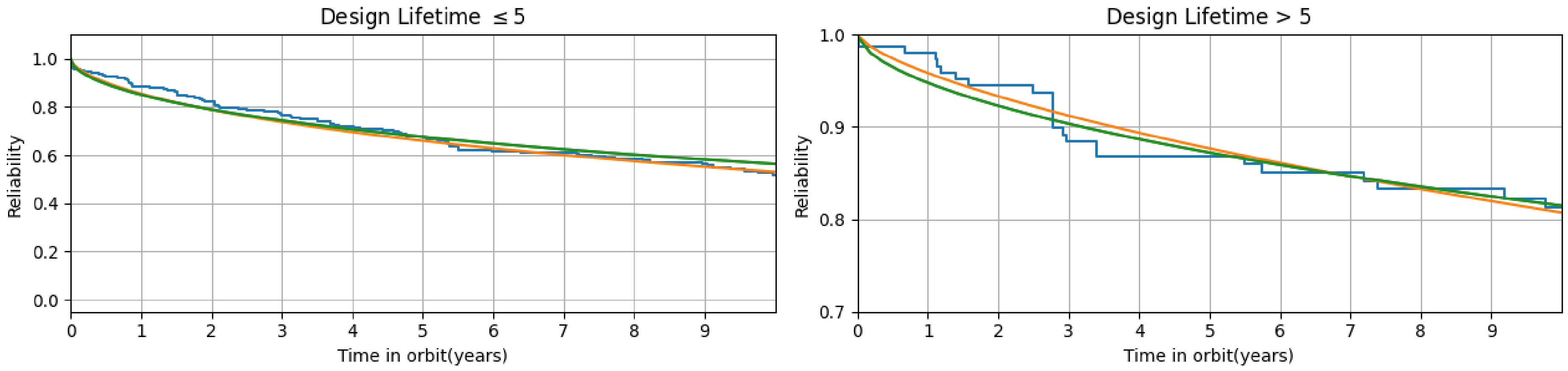
Reliability of different satellite developer categories

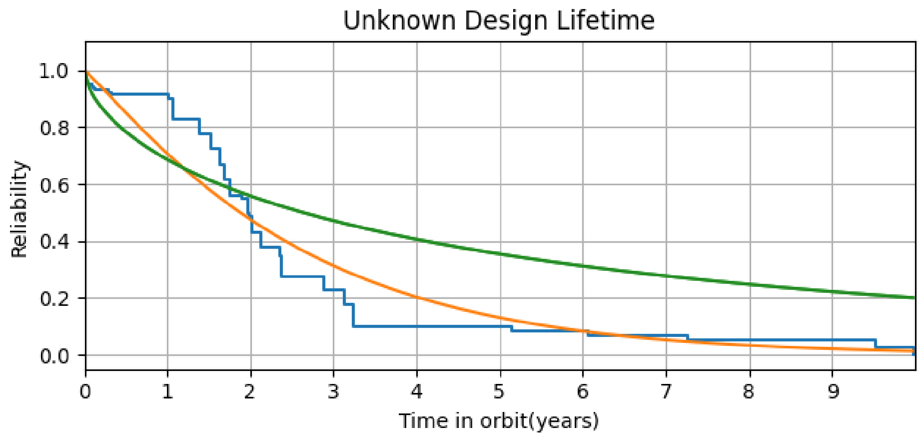


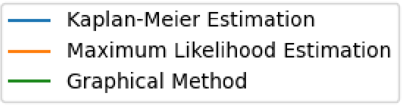


Mission	Graphical - Method		MLE	
	α [years]	β	α [years]	β
Government	13.6189	0.6205	10.9829	0.6894
Private	71.1911	0.5256	52.9258	0.5777
University	36.3287	0.3138	24.2146	0.3818

Reliability for different design lifetime



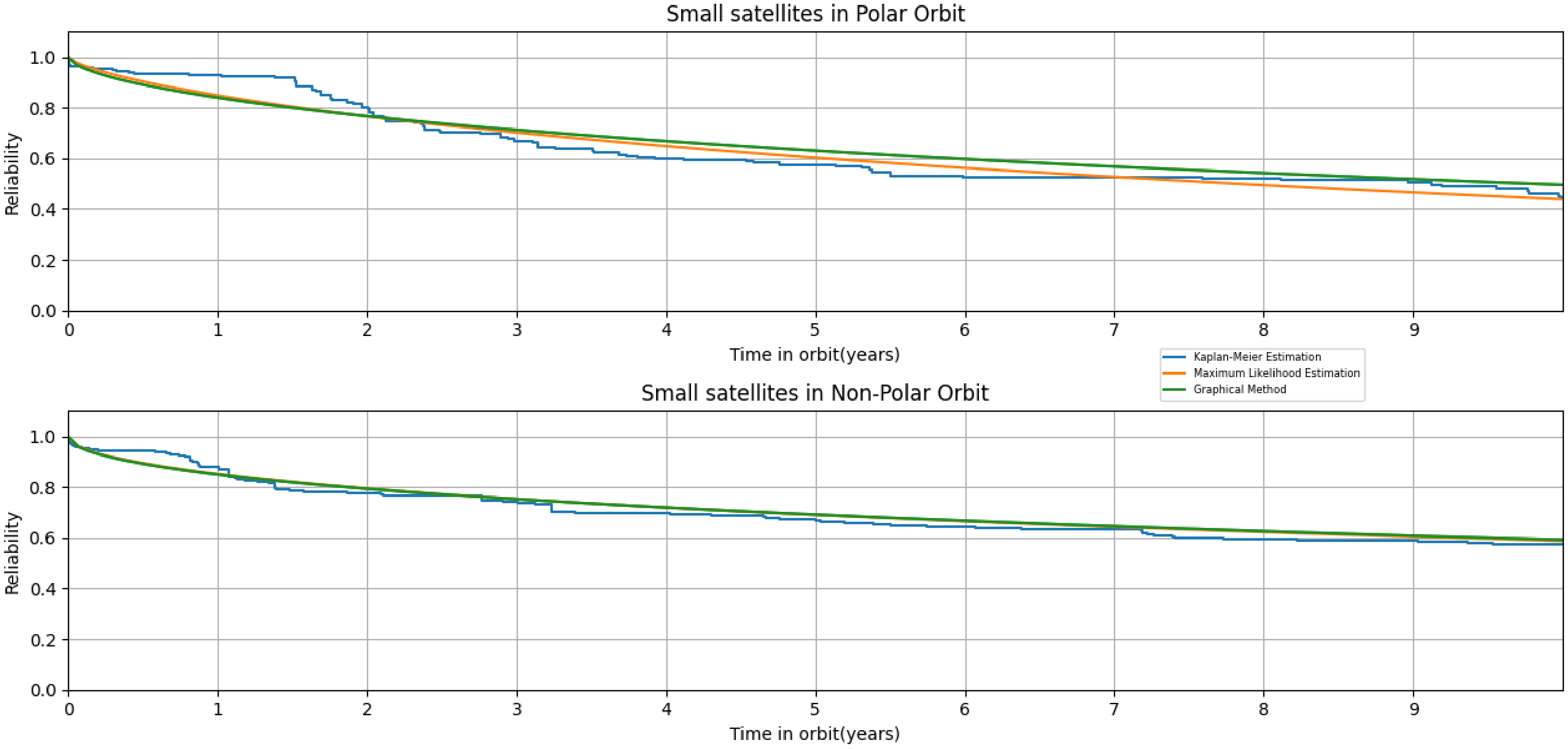




Mission	Graphical - Method		MLE	
	α [years]	β	α [years]	β
≤ 5	27.4768	0.5494	21.2312	0.6063
> 5	151.9503	0.5828	89.7667	0.7025
Unknown	4.7005	0.6302	2.6167	1.1012

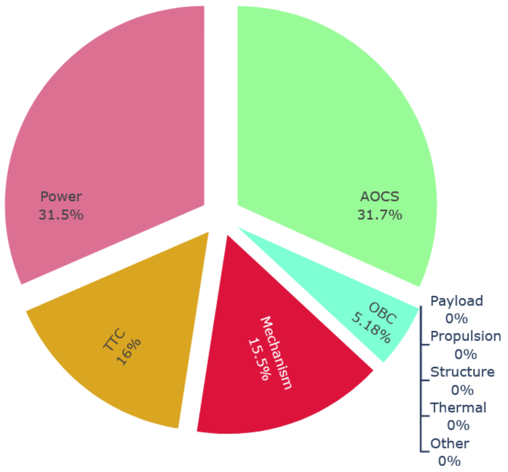
Reliability for different inclination

Mission	Graphical - Method		MLE	
	α [years]	β	α [years]	β
Polar	18.0388	0.6034	13.2237	0.7008
Non-Polar	35.6253	0.5082	33.5043	0.5220

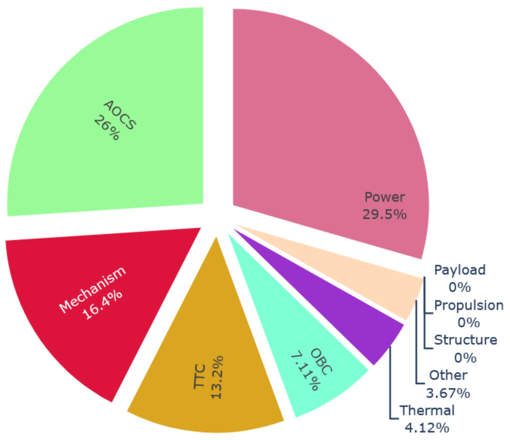


Relative contribution of each subsystem to failure

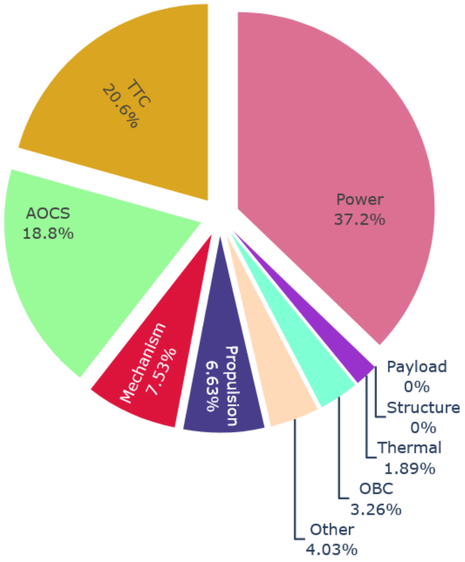
30 days



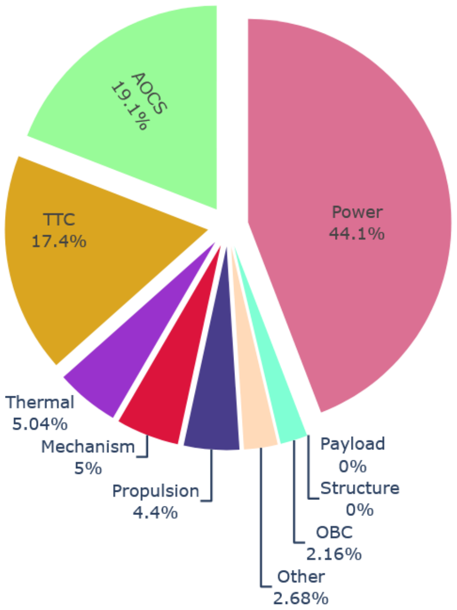
1 year



5 years



10 years



- Statistical reliability of 866 small satellites with launch mass between 40kg - 500kg were investigated.

- Shape Parameter < 1
  - ➢ Infant mortality

- Comparative analysis of subsystem failures
  - ➢ Power Subsystem

- The result presented in this paper helps the small satellite developers to understand the reliability trends in small satellites and various factors that contribute to the satellite's failure, thus supporting the decision-making process

Thank you !!

Questions ??

raja.pandiperumal@uni.lu