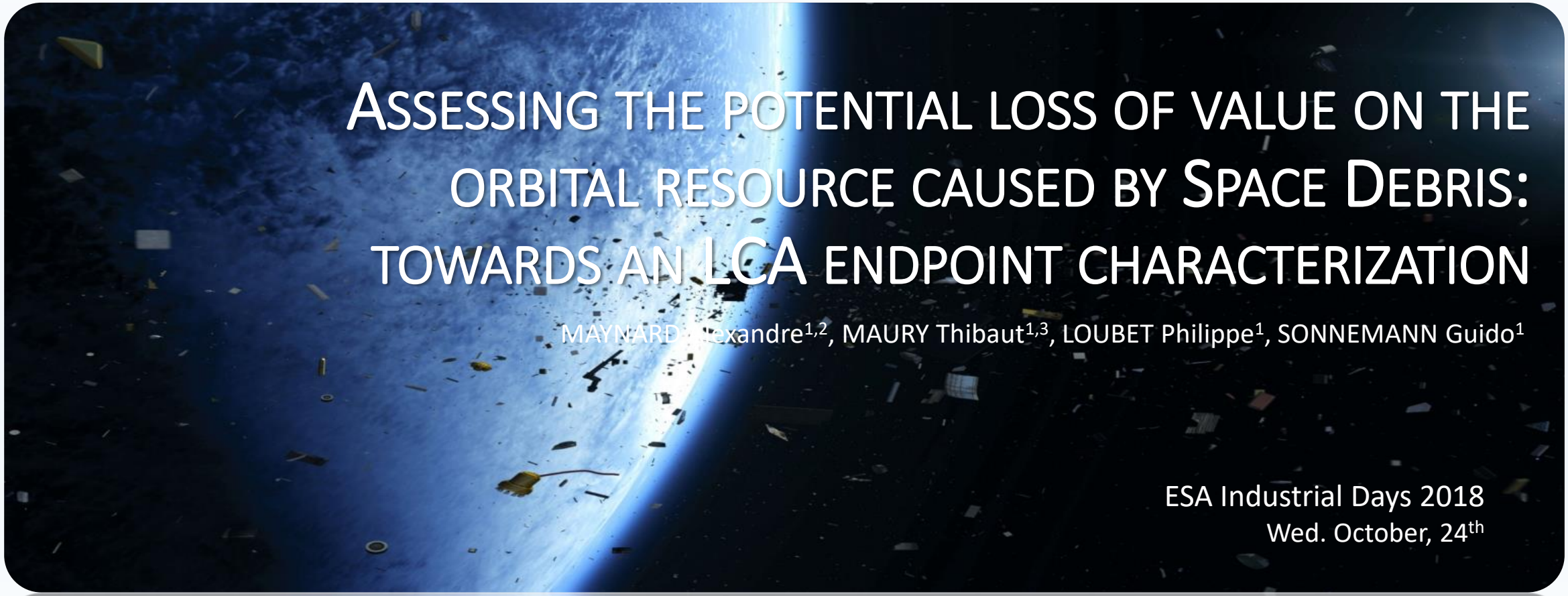

ASSESSING THE POTENTIAL LOSS OF VALUE ON THE ORBITAL RESOURCE CAUSED BY SPACE DEBRIS: TOWARDS AN LCA ENDPOINT CHARACTERIZATION

MAYNARD Alexandre[1,2], MAURY Thibaut[1,3], LOUBET Philippe[1], SONNEMANN Guido[1]

ESA Industrial Days 2018
Wed. October, 24th

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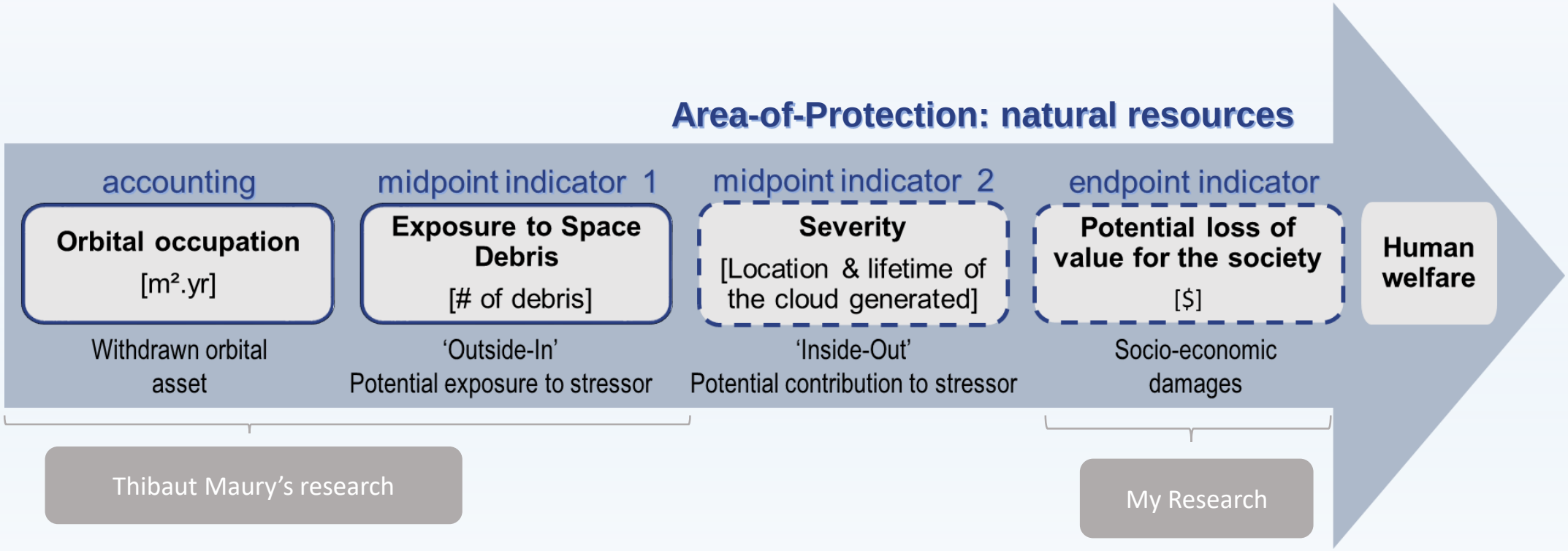
[2] *Faculty of Economic and Management Sciences,* Université de Bordeaux
[3] *Ariane Group, Design for Environment, BP 20011, F-33165 St Médard en Jalles, France*

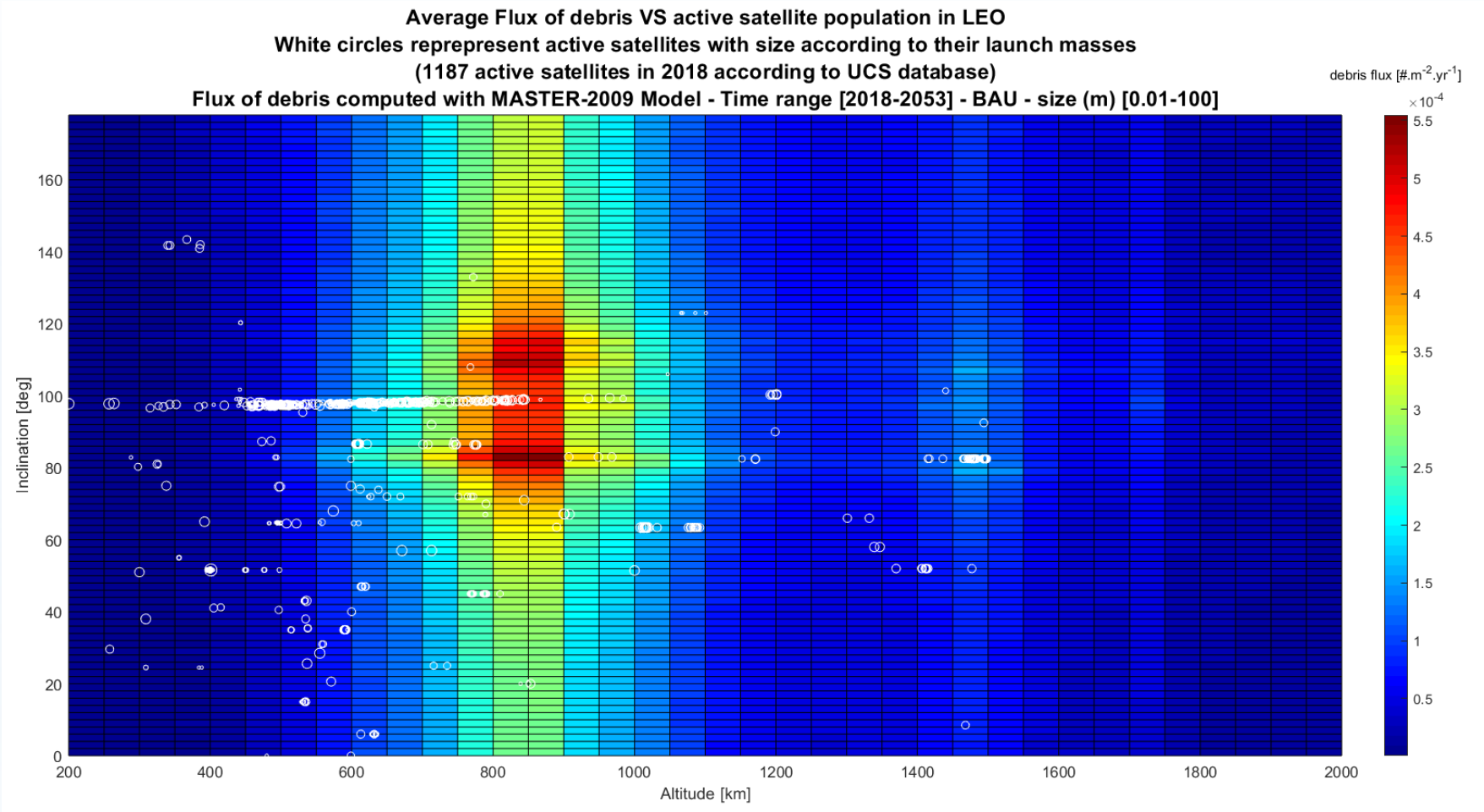
Summary

1. Context
2. Goal and scope
3. Methodology
4. Results
5. Discussions

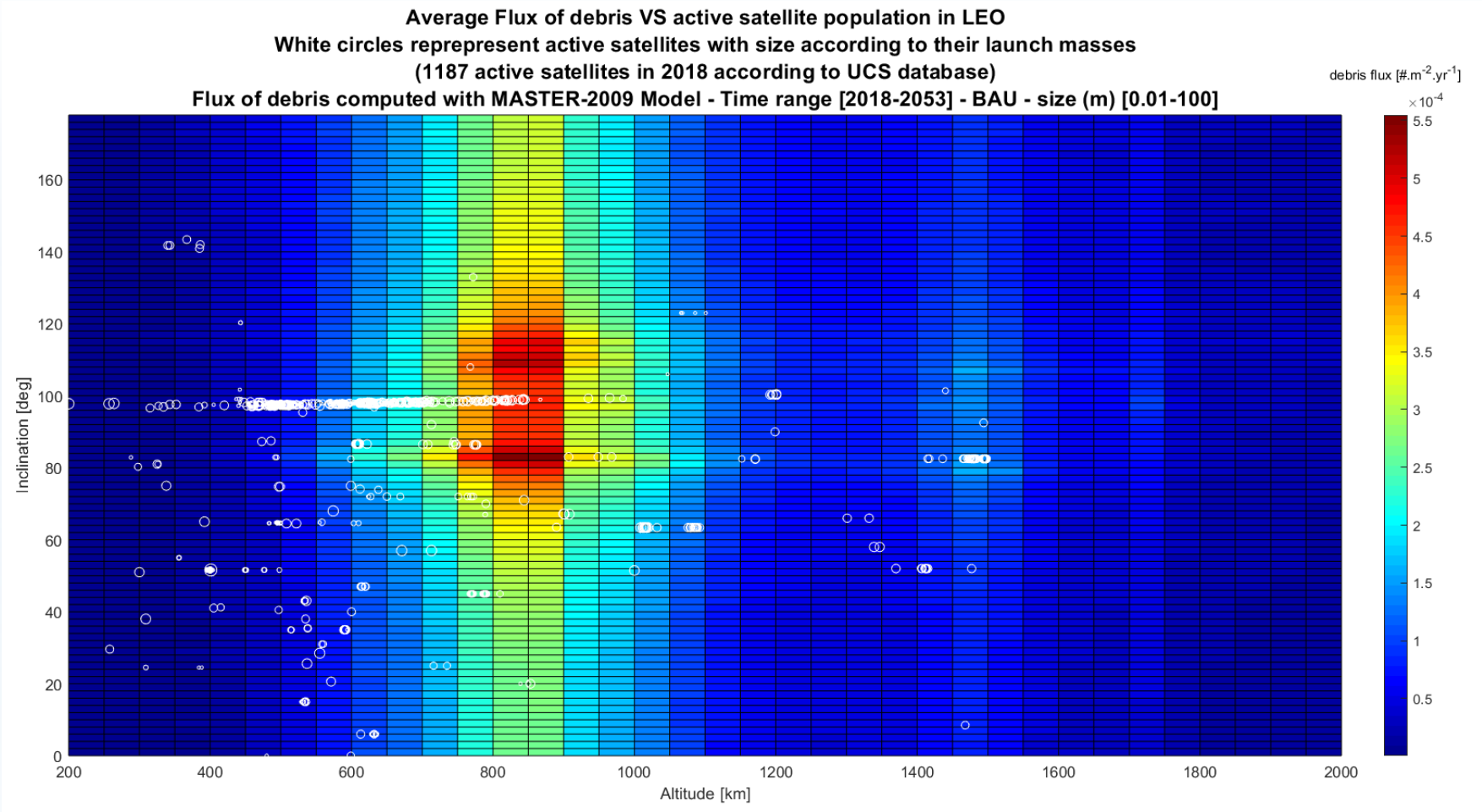
1. Added value of assessing the social-economic impact of the orbital resource


Area-of-Protection: natural resources
accounting
midpoint indicator 1
midpoint indicator 2
endpoint indicator
Orbital occupation
[m².yr]
Exposure to Space Debris
[# of debris]
Severity
[Location & lifetime of the cloud generated]
Potential loss of value for the society
[$]
Human welfare
Withdrawn orbital asset
'Outside-In'
Potential exposure to stressor
'Inside-Out'
Potential contribution to stressor
Socio-economic damages
Thibaut Maury's research
My Research

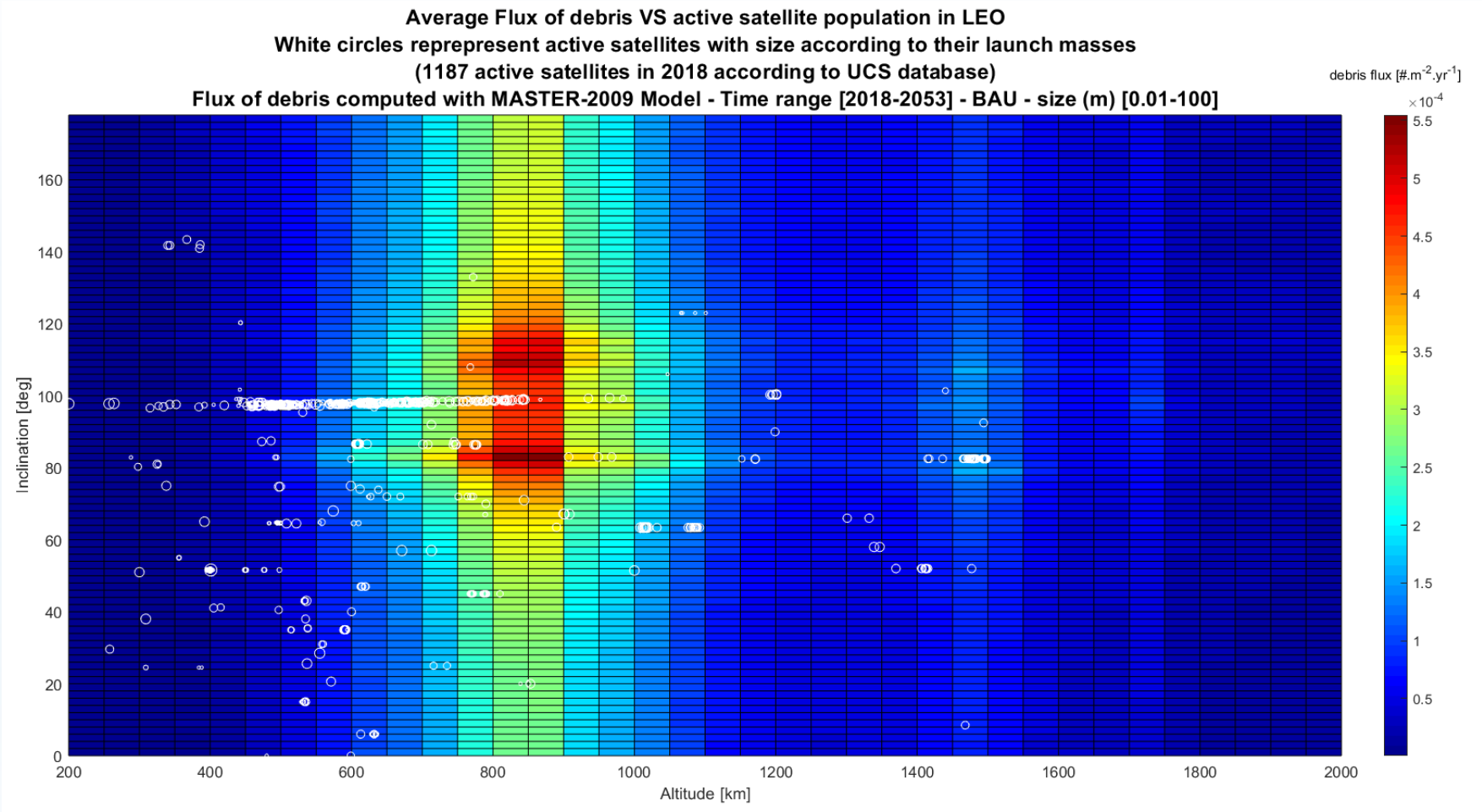
2. Goal and scope



Value of the orbital resource



Value of the orbital resource → The values of actives satellites



Value of the orbital resource → The values of actives satellites

The aim is to compute the value that could be depleted if a satellite is impacted by debris before the end of its mission.

Goal of the study

Make a valuation of each satellite revenue per year according to:

- its mission
- Its instruments, performances or specificities
- its age

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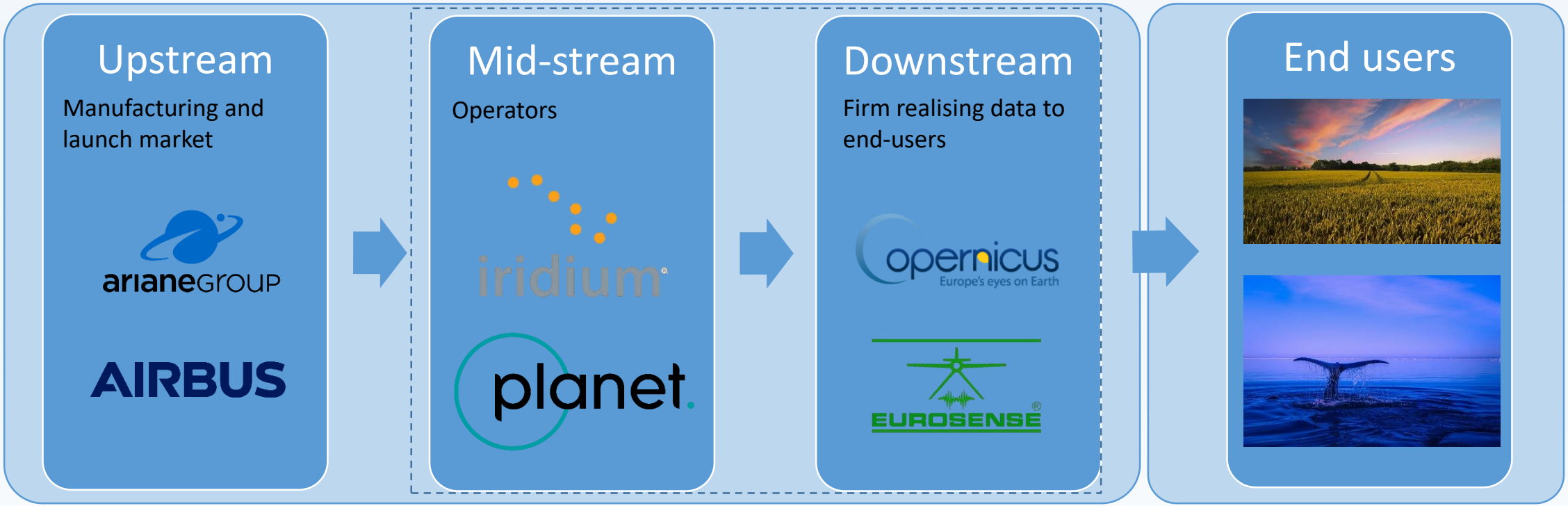
- The idea is to address the potential loss of value for the **society** if a collision occurs
- **Focus on the End-user benefits**

Space-sector structure



Space-sector revenues

Overall society Benefits

Scope

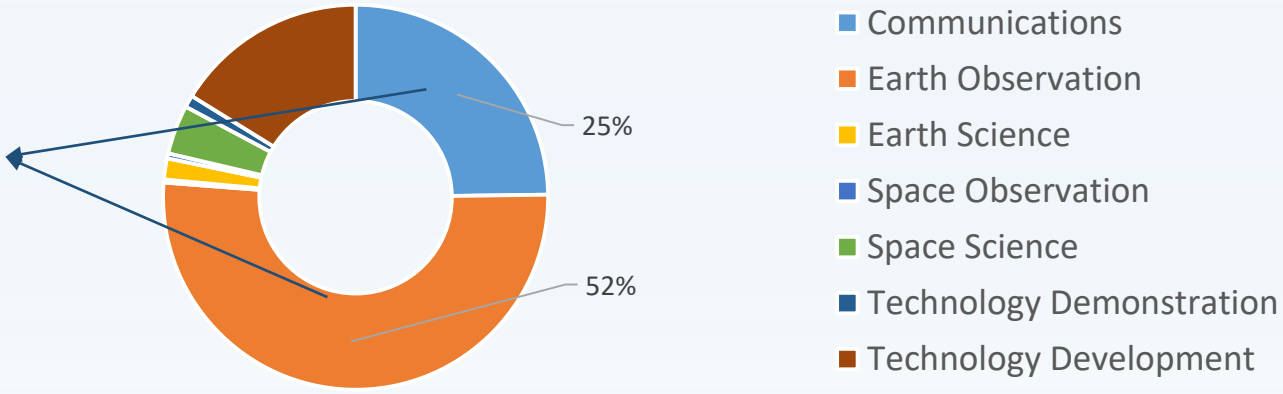
a) Geographical perimeter of the valuation

- Low Earth Orbit : 75% of the catalogued population in less than 1% of useful orbital volume

b) Inventory perimeter of the valuation

Repartition of the 1186 LEO satellites according there mission

Both missions represent 77% of total actives satellites



Source : UCS Database

c) Time perimeter of the valuation

- No future launch hypothesis
- Gives the valuation at the assessment date (reference year: 2018)

4. Methodology

a. Earth Observation satellites - valuation methodology

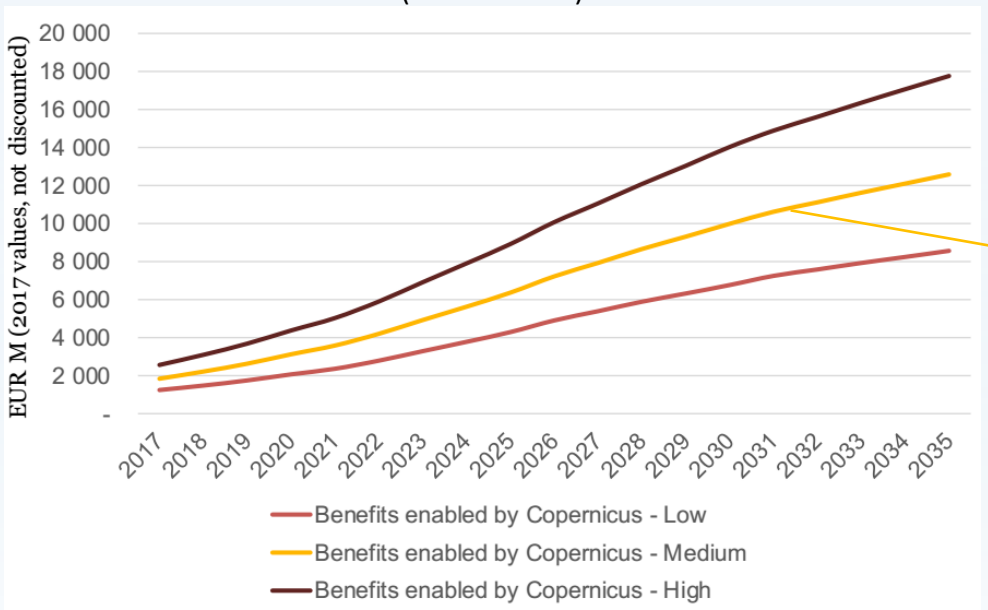
b. Communication satellites - valuation methodology

a. Earth Observation satellites valuation methodology

Earth Observation satellites' value

Revenues for End-users allows by Copernicus Program

(Source : Pwc)

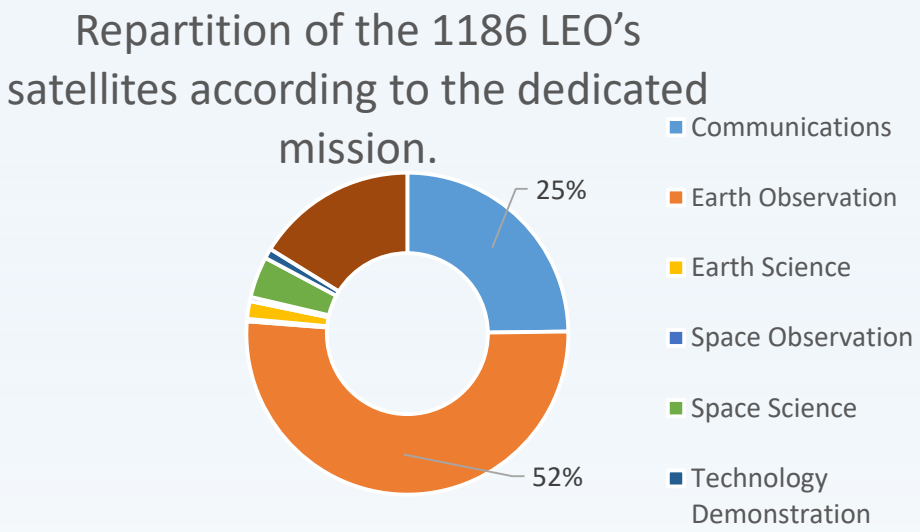


The aim is to extend revenues from Copernicus program to other Earth observation satellites

Hypothesis :

- Life Time of satellites : 1,93 times the official life time (based on average additional life time)
- Cutting rule : a satellite that is older than 2 times this estimated life time has negligible outcomes.

Earth Observation satellites valuation methodology



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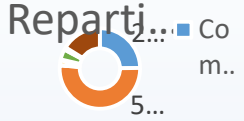
Earth observation: 637 satellites

Earth Observation satellites valuation methodology



Copernicus' revenues

WMO OSCAR database : score per on-board instrument

Copernicus : 62 satellites (≈10%)

Data

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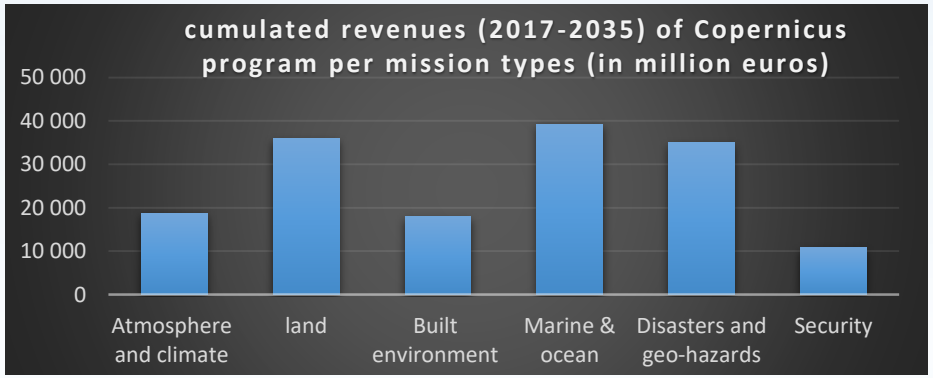

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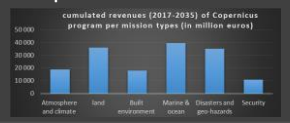

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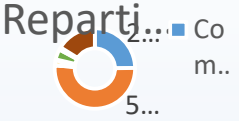

Copernicus' revenues

Participation of each Copernicus satellite to the mission classes

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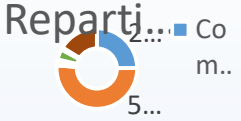

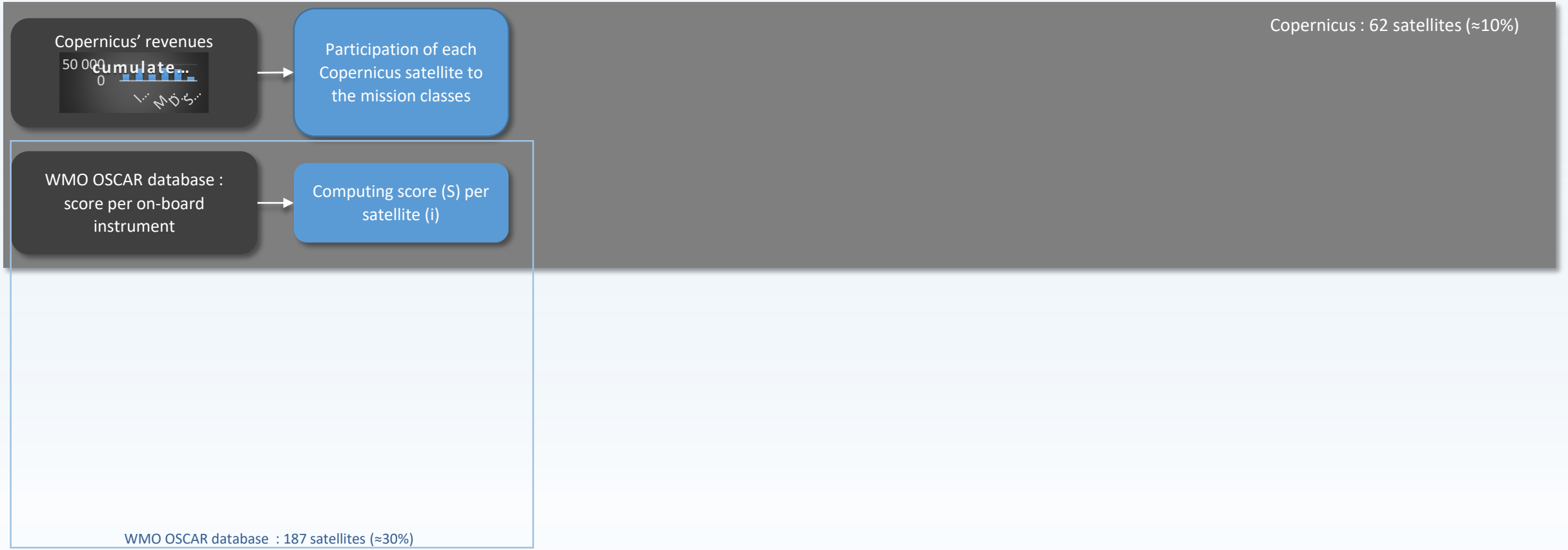

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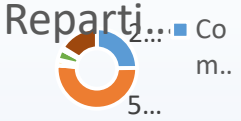

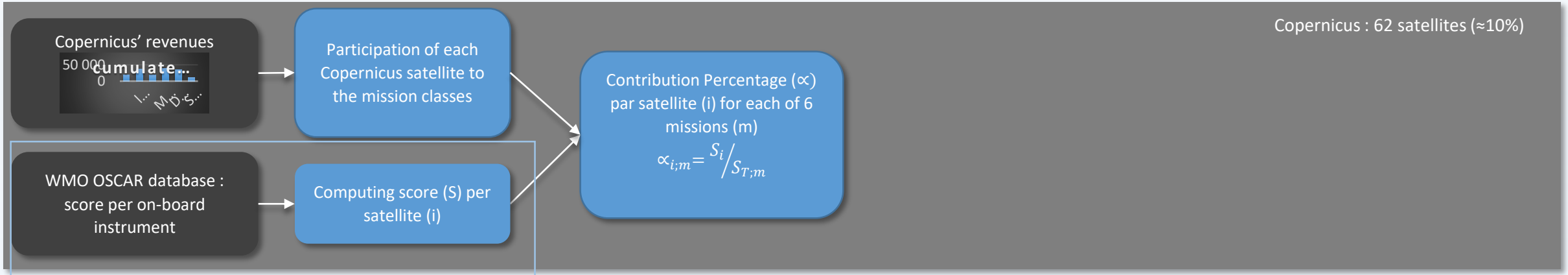

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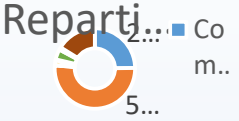

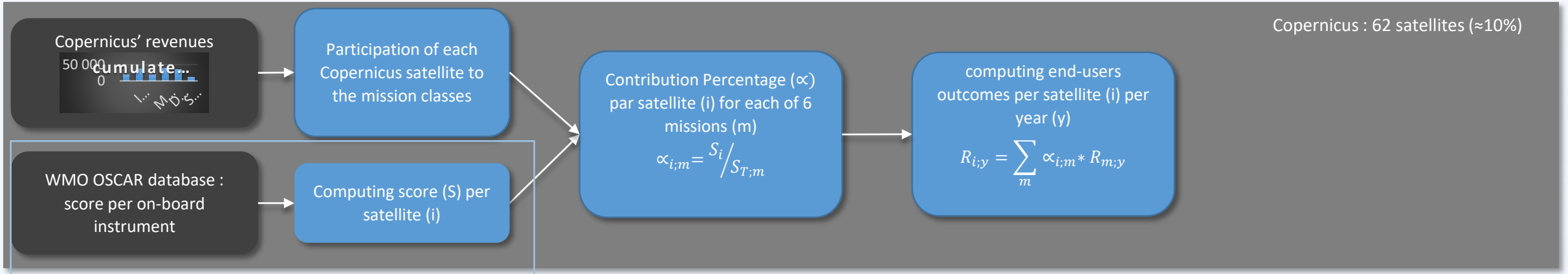

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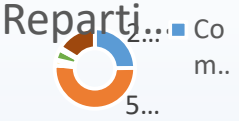

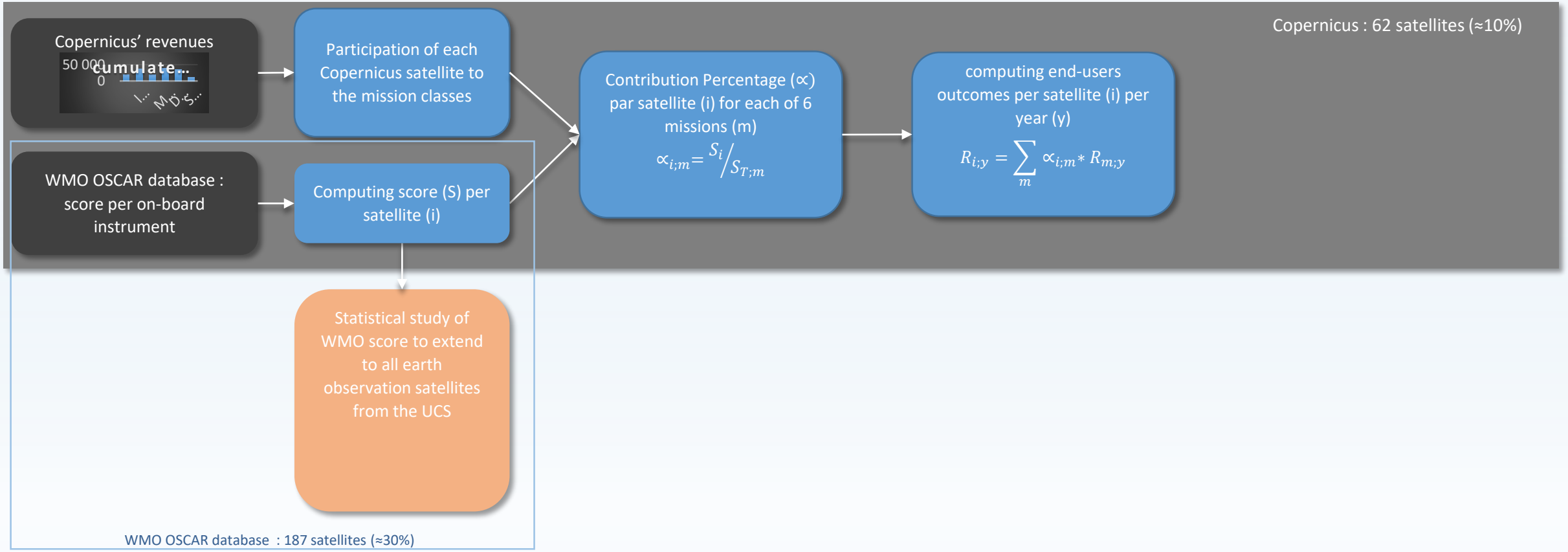

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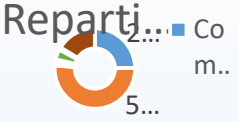

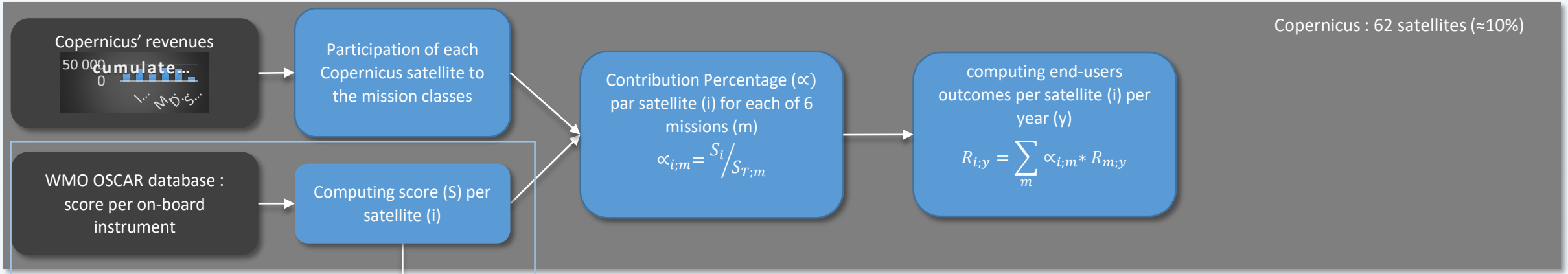


```
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      Source |       SS       df       MS              Number of obs =     175
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       Model |  223.993309     6  37.3322182            Prob > F      =  0.0000
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-------------+------------------------------           Adj R-squared =  0.4328
       Total |  495.181032   174     2.845868          Root MSE      =  1.2705

------------------------------------------------------------------------------
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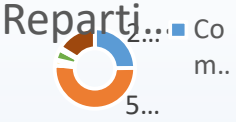
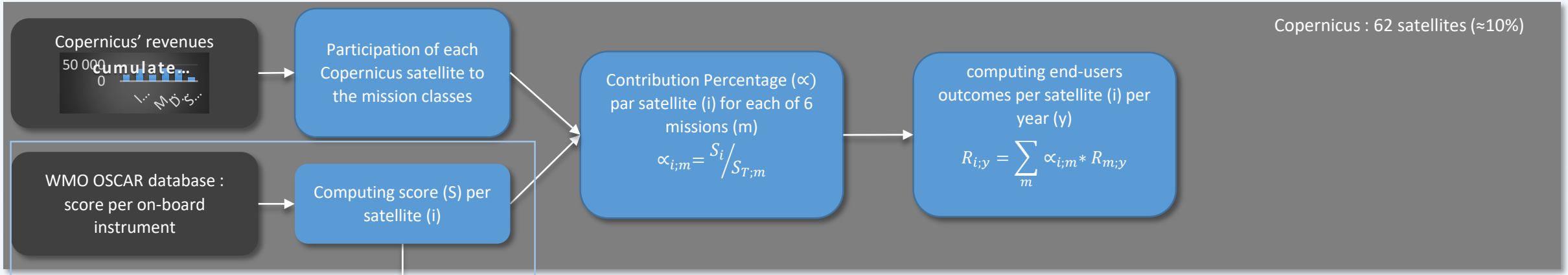
Data

Steps with uncertainties

Earth observation: 637 satellites

Earth Observation satellites valuation methodology



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Earth observation: 637 satellites

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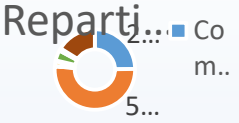

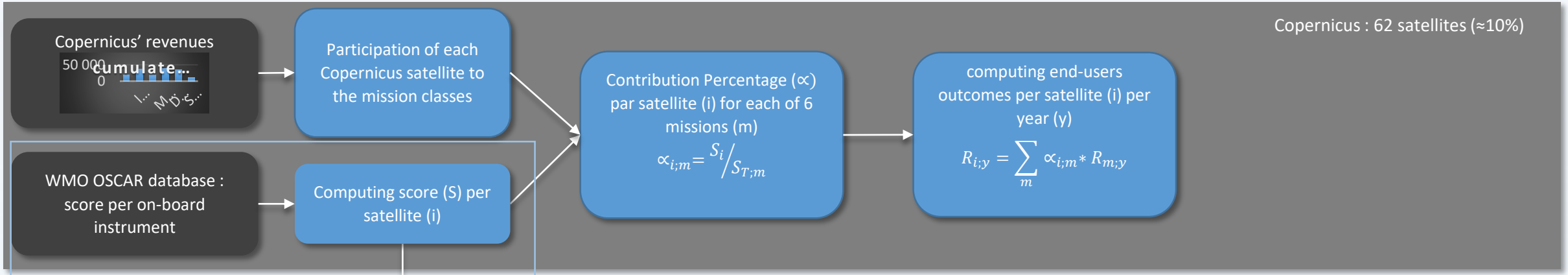


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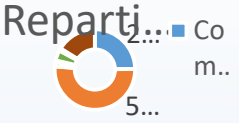
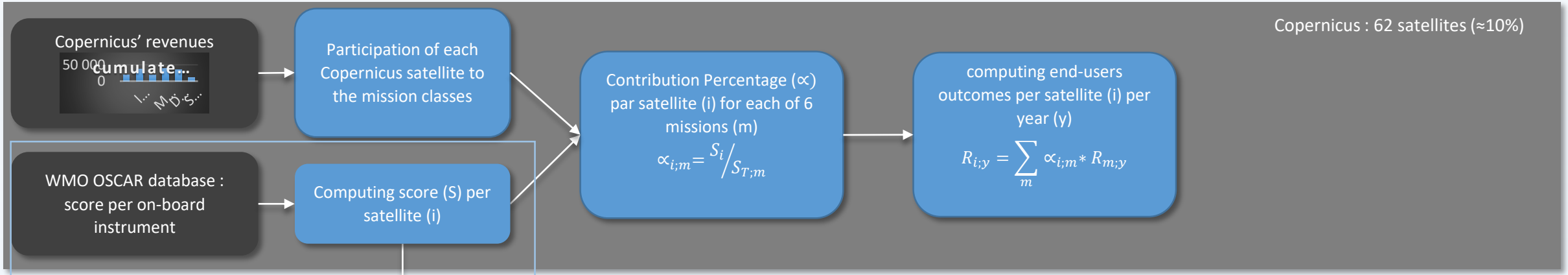
Earth observation: 637 satellites

Earth Observation satellites valuation methodology



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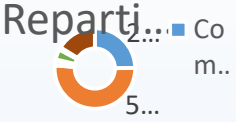
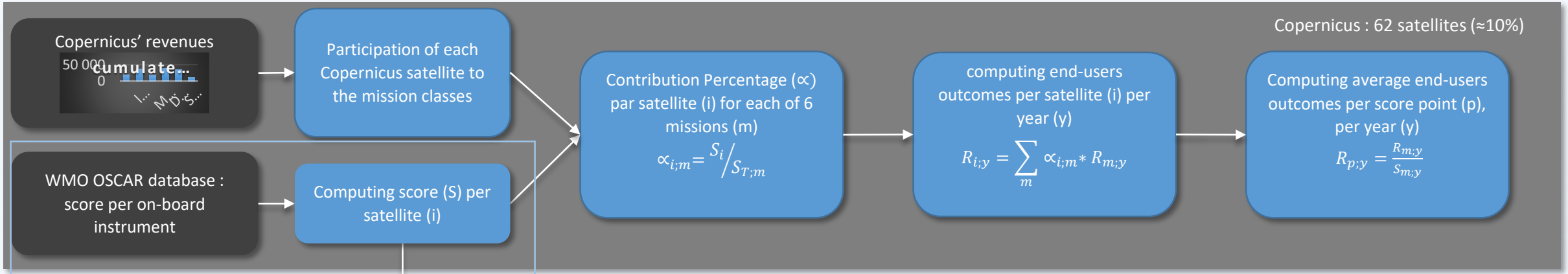
Earth observation: 637 satellites

Earth Observation satellites valuation methodology



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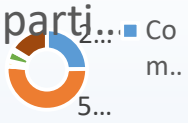


Copernicus' revenues

Participation of each Copernicus satellite to the mission classes

WMO OSCAR database : score per on-board instrument

Computing score (S) per satellite (i)

Contribution Percentage (∝) par satellite (i) for each of 6 missions (m)

$$\propto_{i;m} = {S_i}/{S_{T;m}}$$

computing end-users outcomes per satellite (i) per year (y)

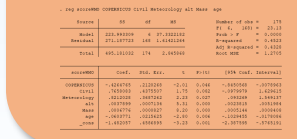
$$R_{i;y} = \sum_m \propto_{i;m} * R_{m;y}$$

Copernicus : 62 satellites (≈10%)

Computing average end-users outcomes per score point (p), per year (y)

$$R_{p;y} = \frac{R_{m;y}}{S_{m;y}}$$

Statistical study of WMO score to extend to all earth observation satellites from the UCS



WMO OSCAR database : 187 satellites (≈30%)

Accessing the increase of outcomes per points due to the free data access in Copernicus program (β)

Computing each satellite end-users outcomes

$$R_{i;y} = R_{p;y} \,.\, S_i \,.\, \beta$$

Sum of actuals values for each cells (50kmx2°)

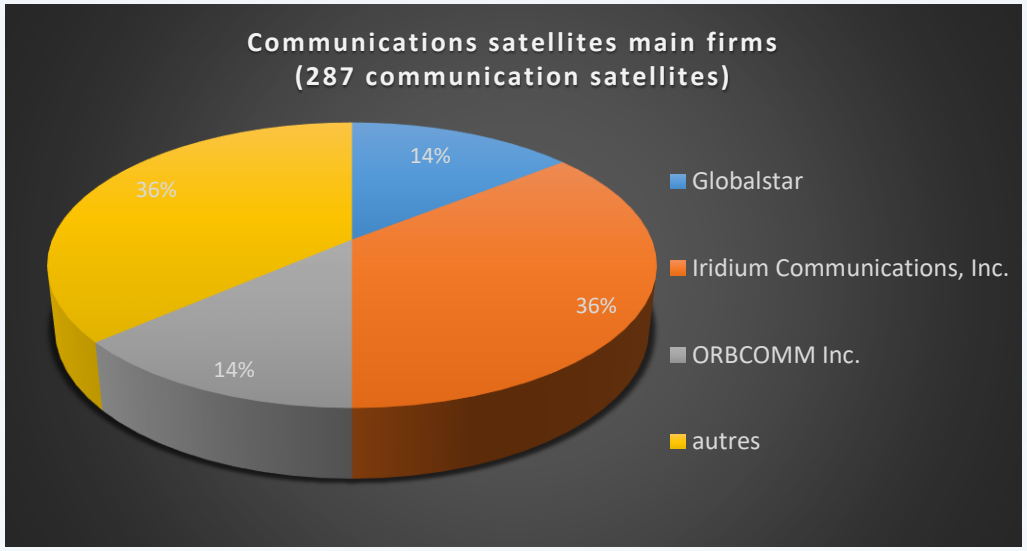
Earth observation: 637 satellites

Data

Steps with uncertainties

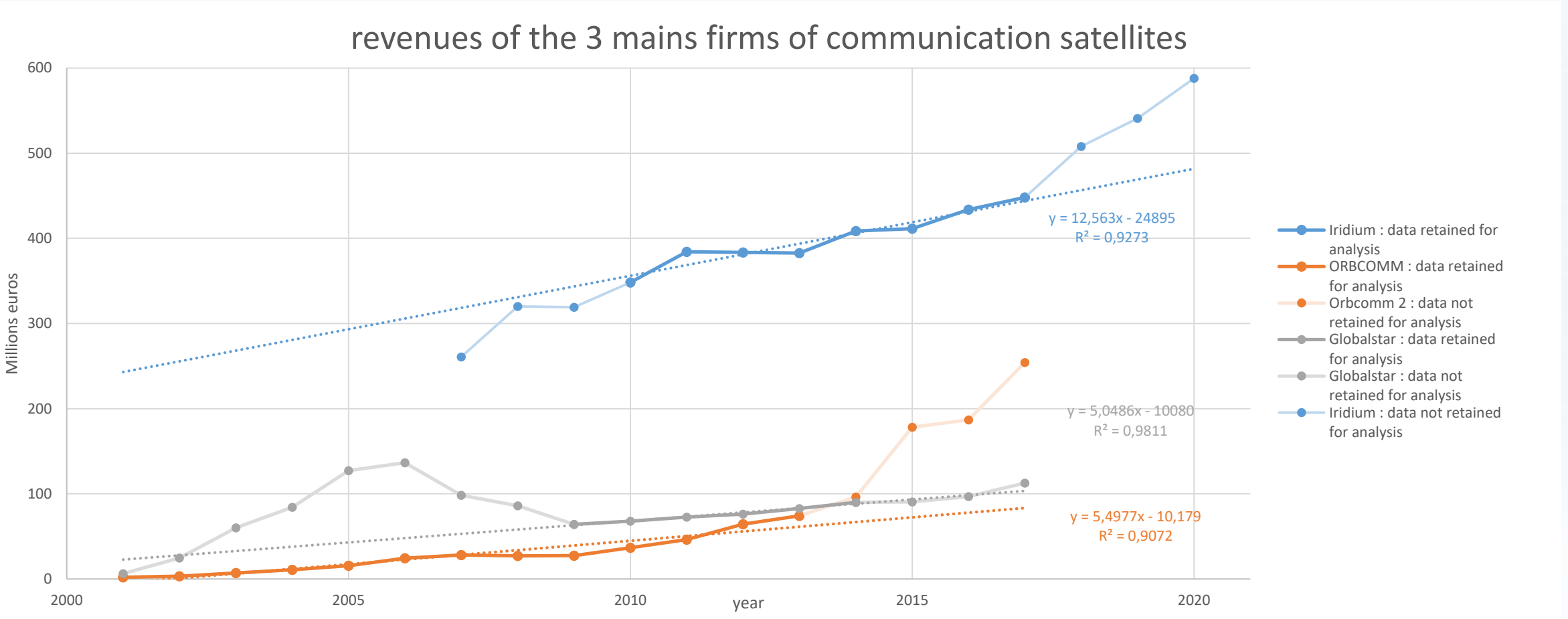
b. Communication satellites valuation methodology

Communication satellites valuation methodology

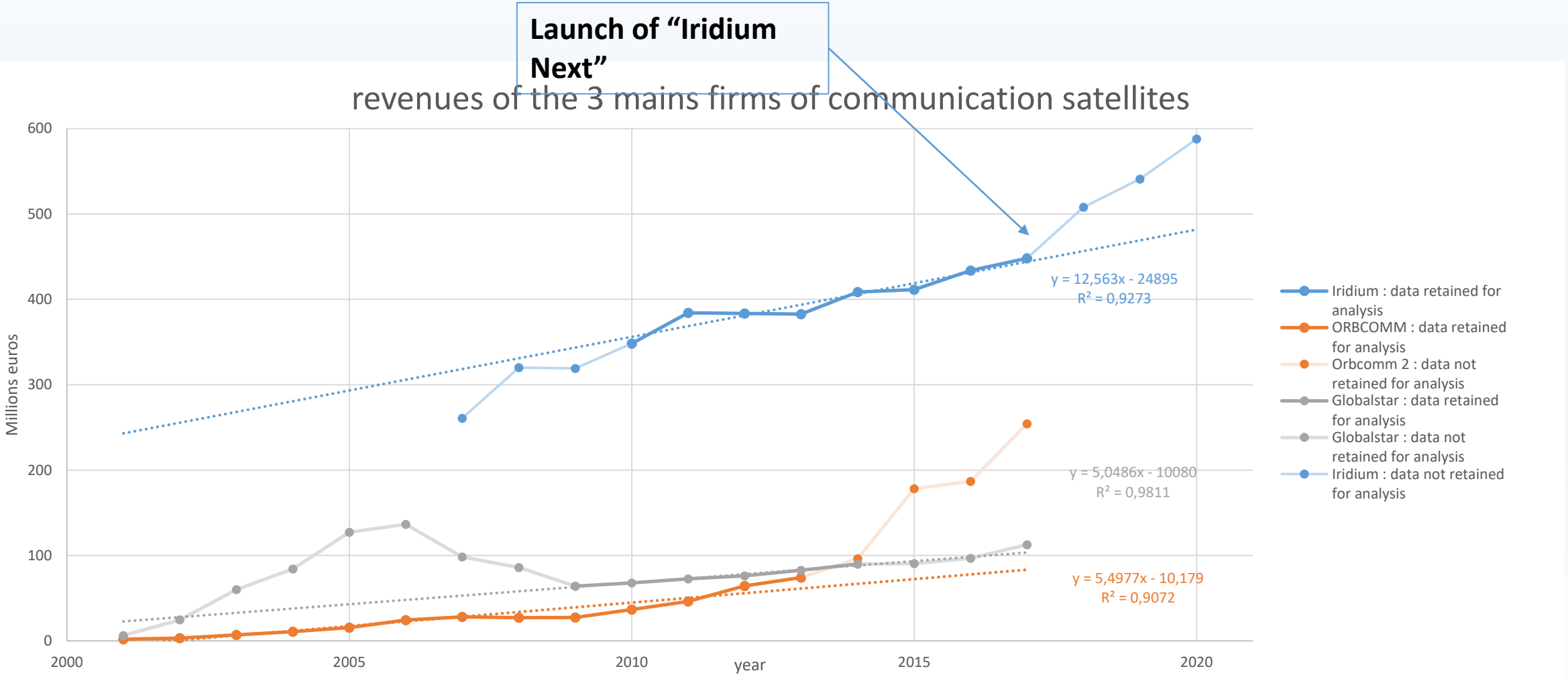


The aim is to assess benefits for the end-users based **on the volume of sales**

Communication satellites valuation methodology



Communication satellites valuation methodology



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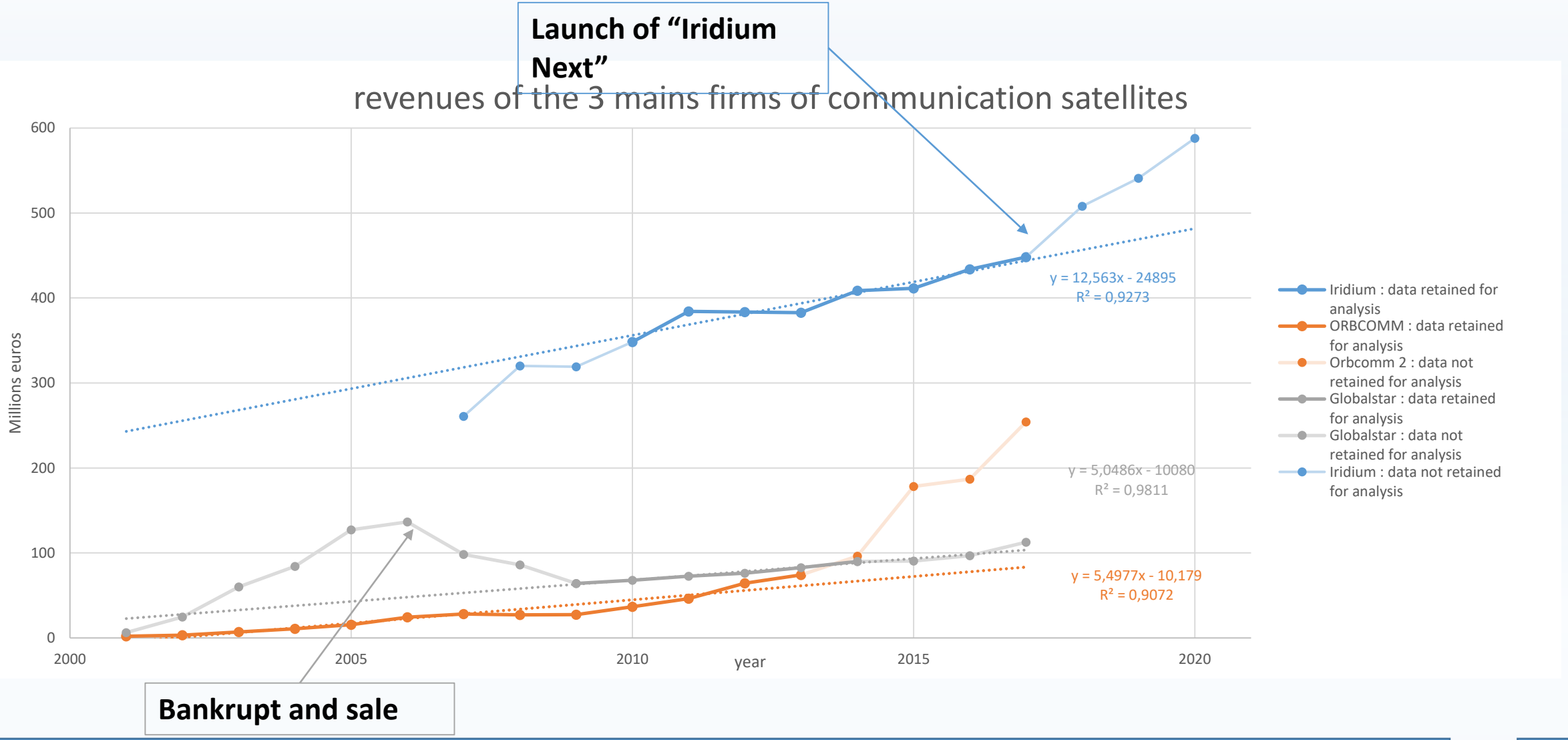
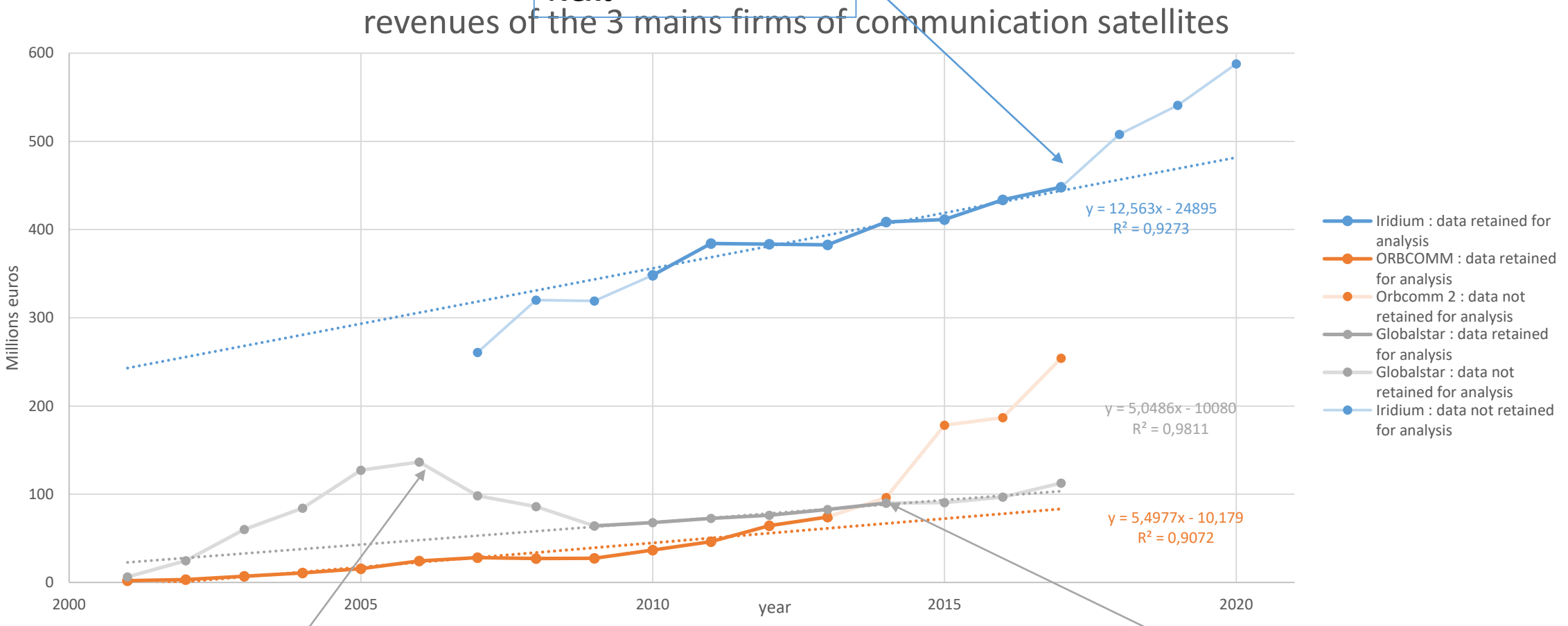


Communication satellites valuation methodology

Launch of "Iridium Next"

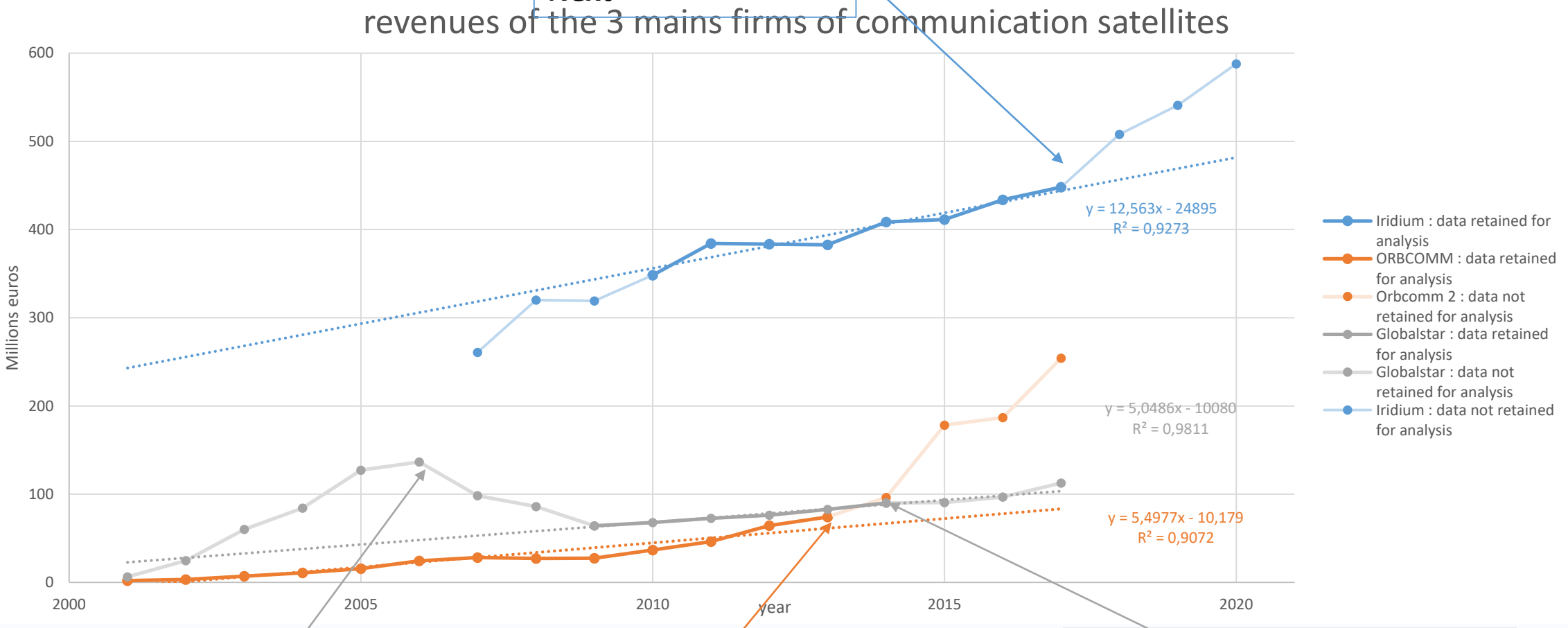


Bankrupt and sale

Globalstar generation 2 launch

Communication satellites valuation methodology

Launch of "Iridium Next"



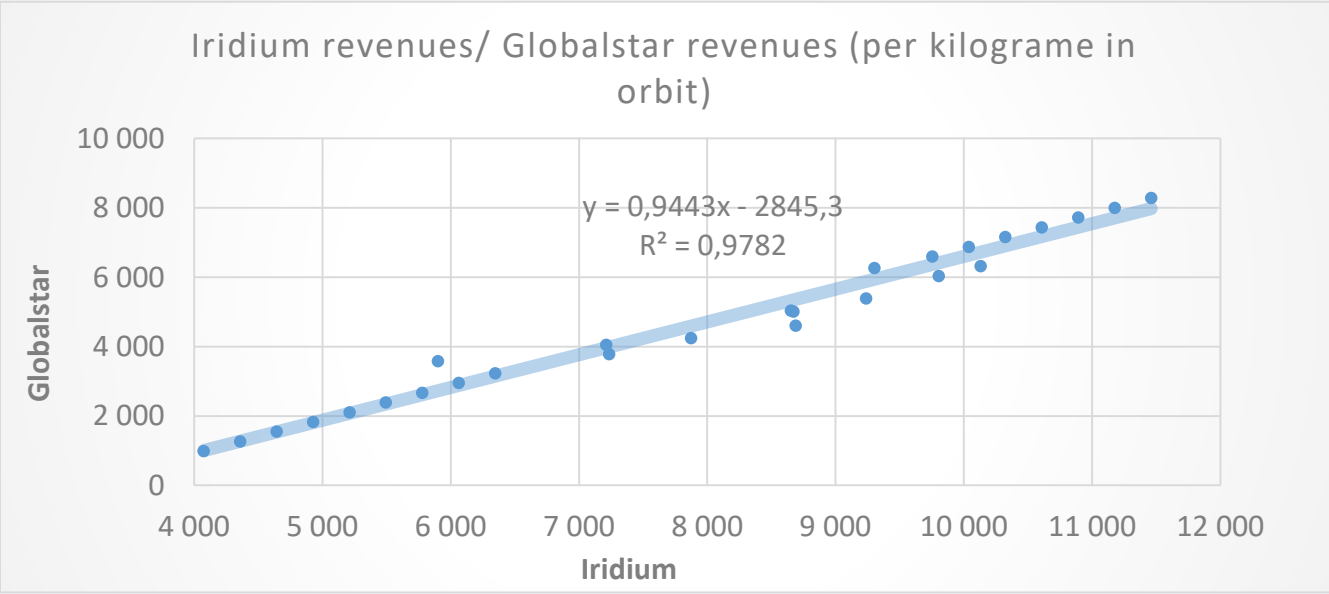
Bankrupt and sale

Orbcomm OG2 launch

Globalstar generation 2 launch

Value allocation hypothesis

- Nano-satellites (<100 kg): similar revenues with Orbcomm's satellites (nano-satellites of 45kg constellation)
- Bigger satellites (>100kg): revenues are indexed on Iridium company revenues. (calibration thanks to Globalstar revenues)



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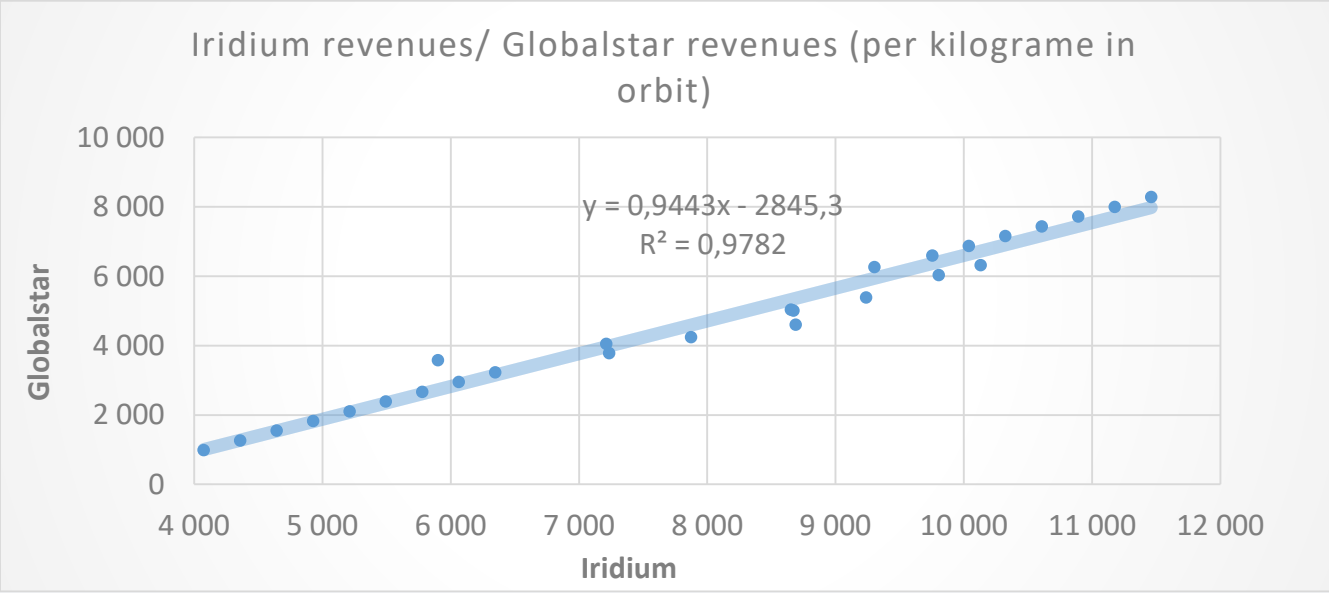

Time Hypothesis :

- Lifetime of satellites : 1,64 times the official life time (based on average additional life time)
- Cutting rule : a satellite that is older than 2 (in 2018) times this estimated life time has negligible outcomes

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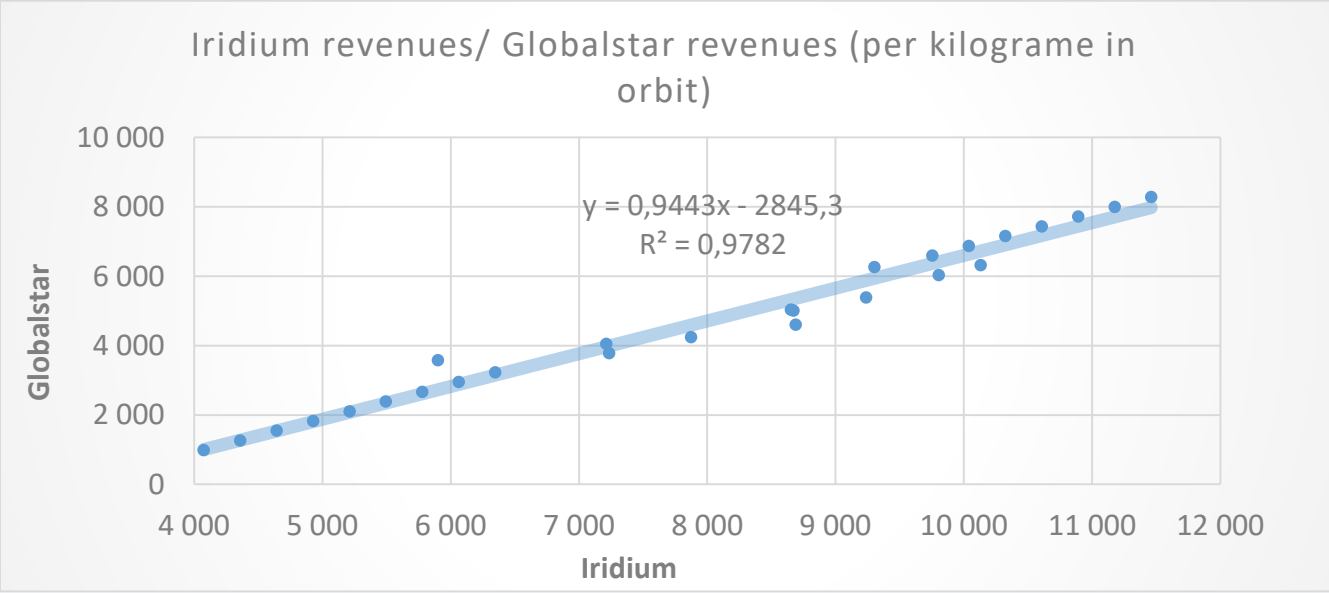

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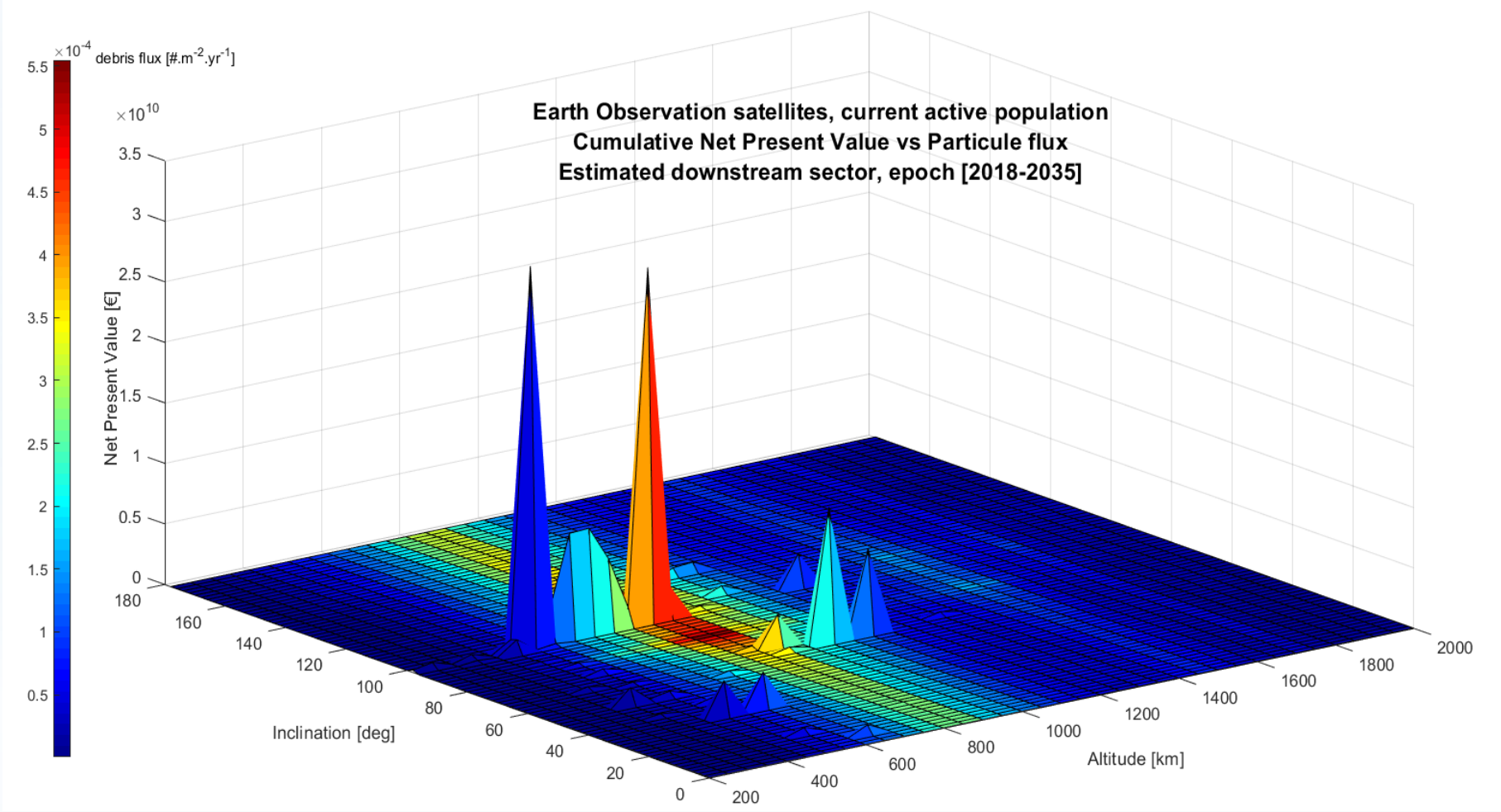
Hypothesis to assess the end-users' benefits

- There is a scale of 1 to 4 for between volume of revenues generated for exploiting firms and the end-users benefits (PWC).

5. results

Results for Earth Observation satellites



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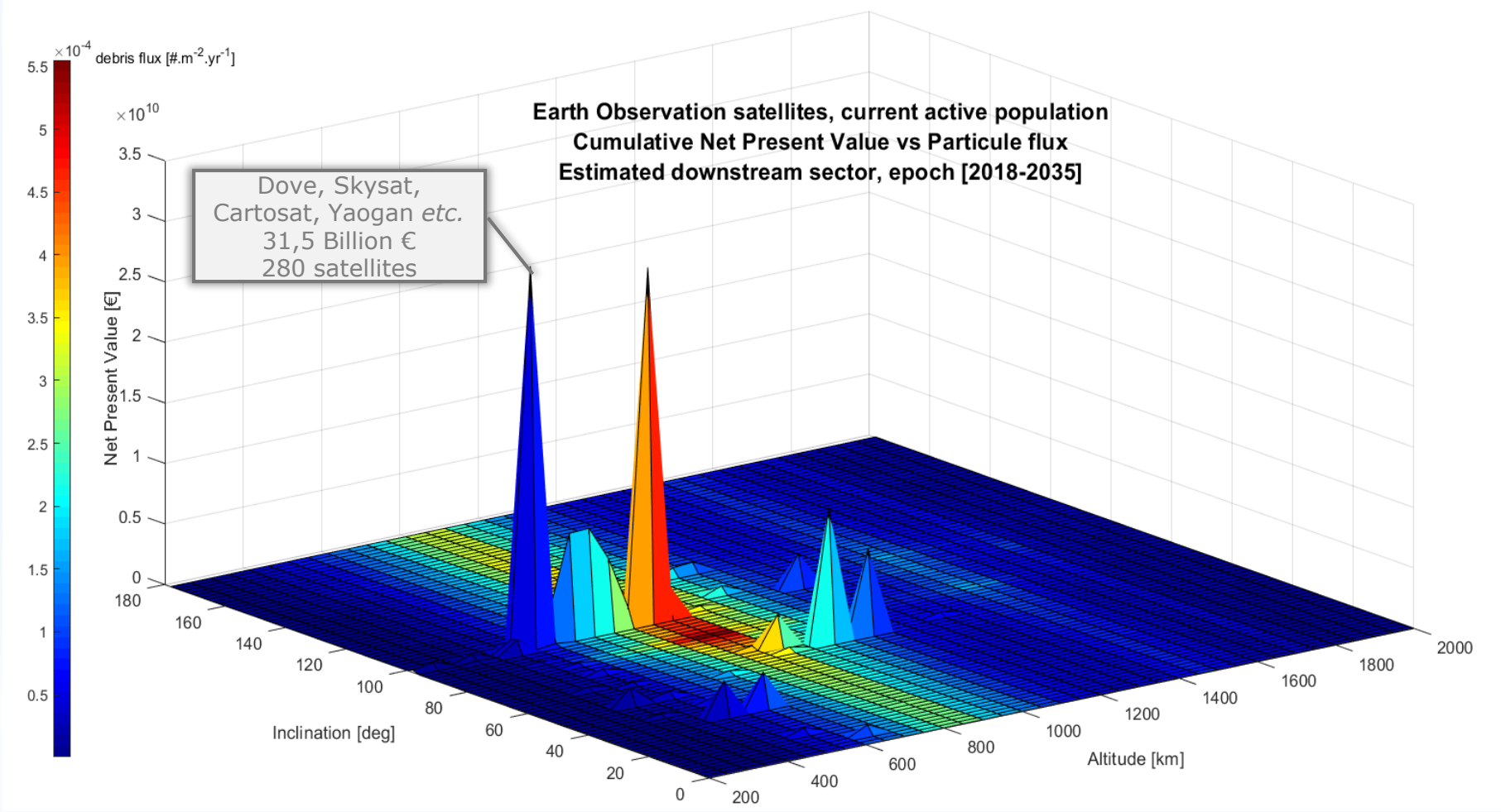

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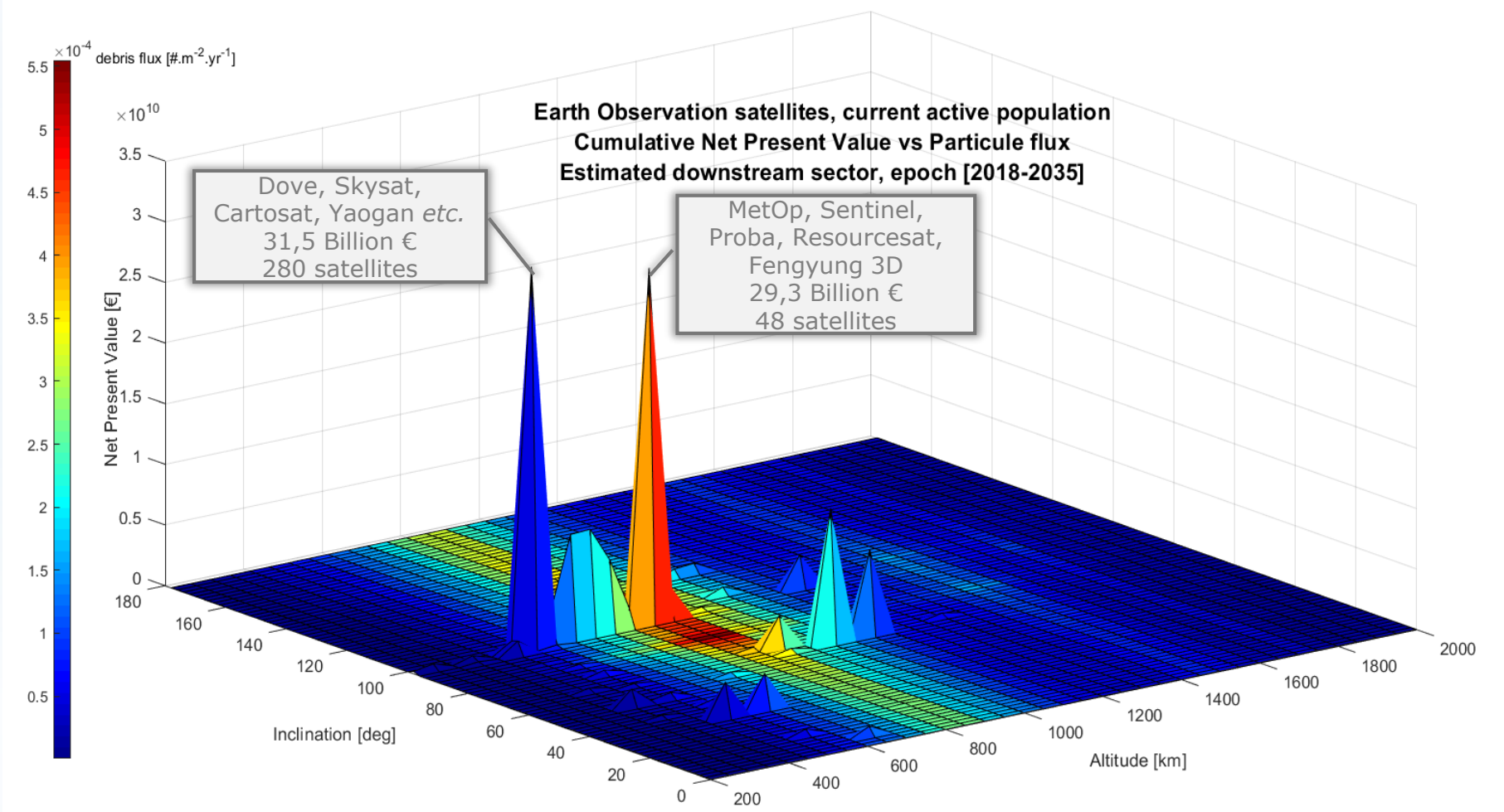

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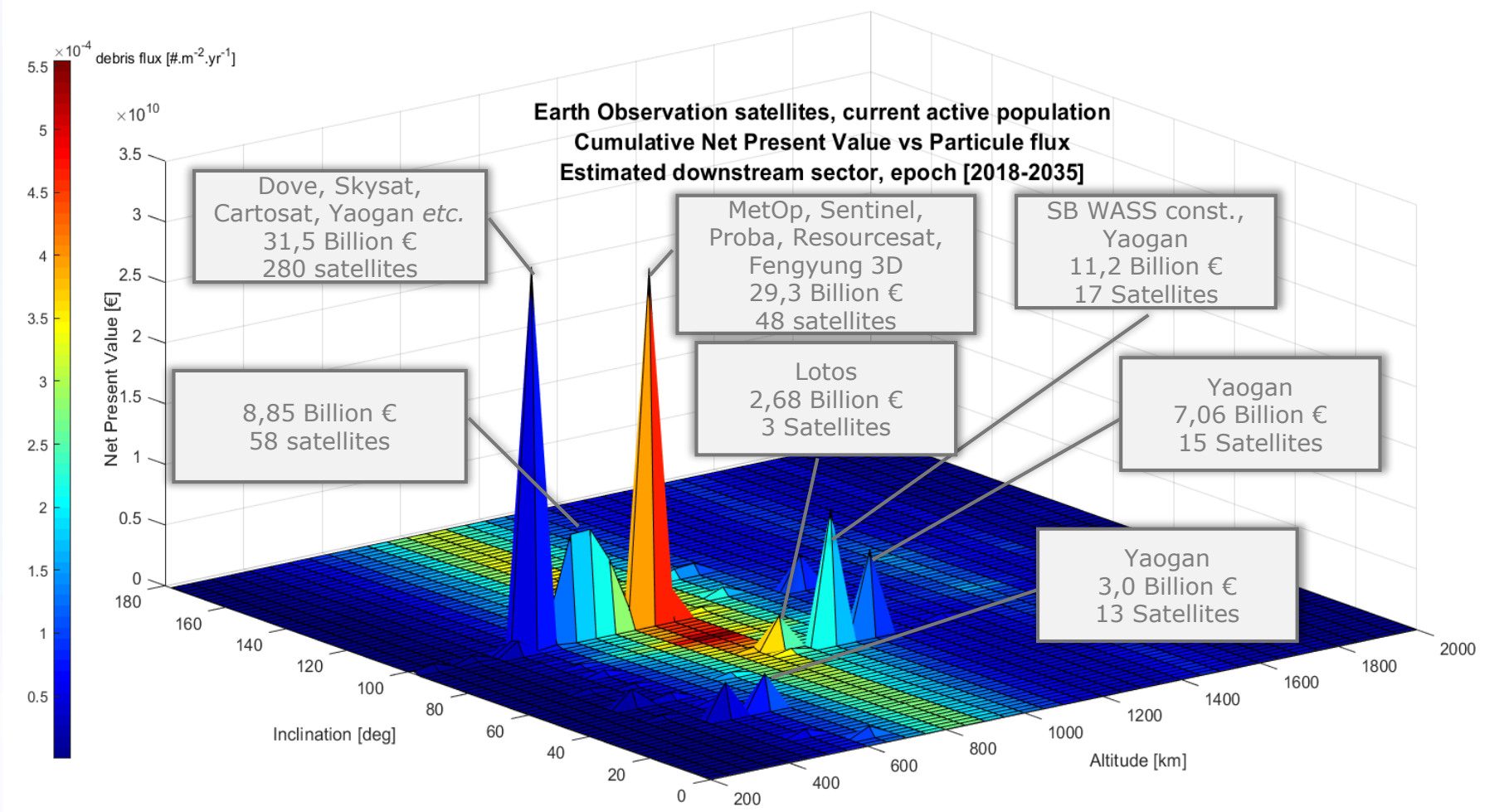
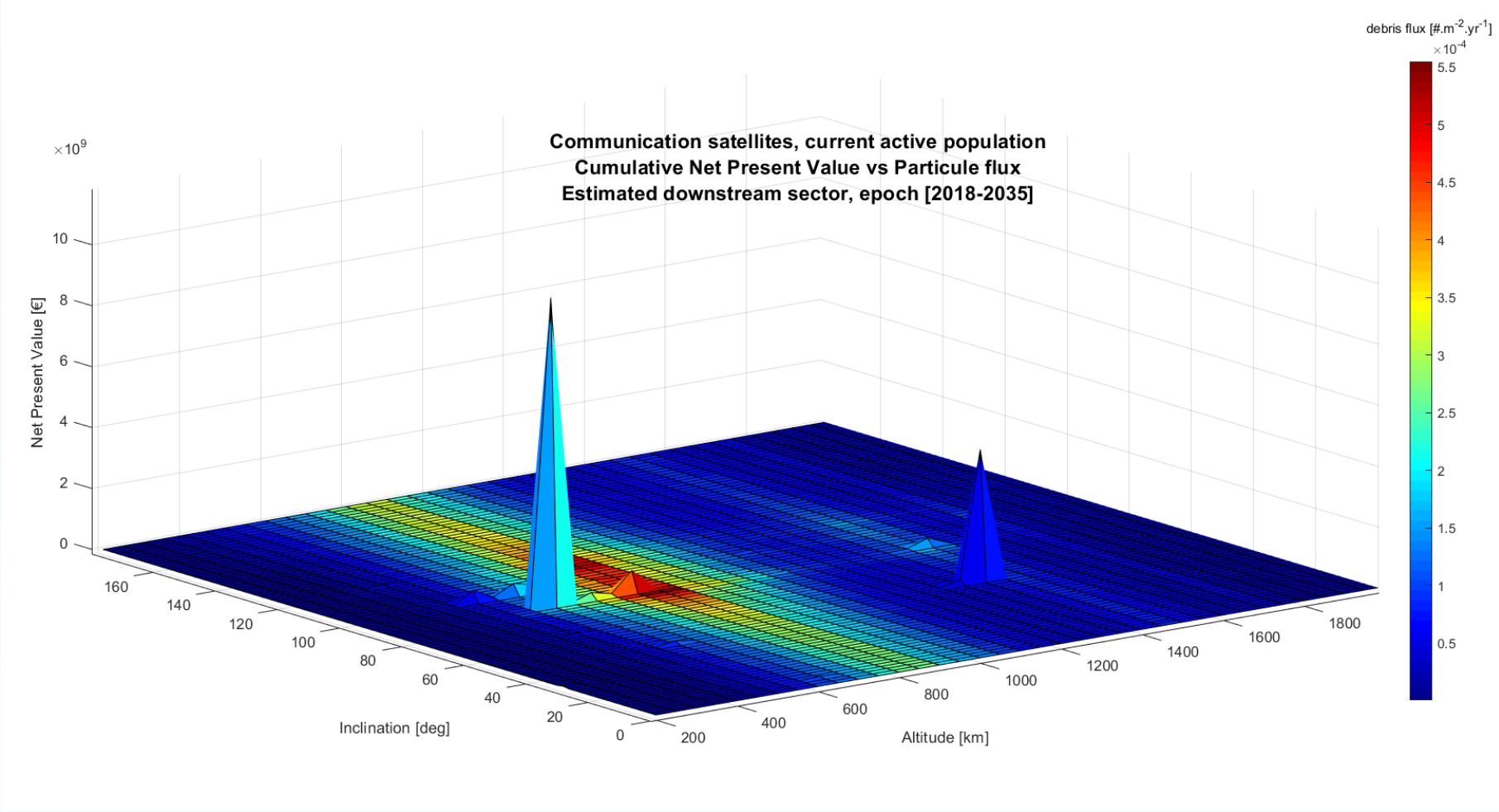
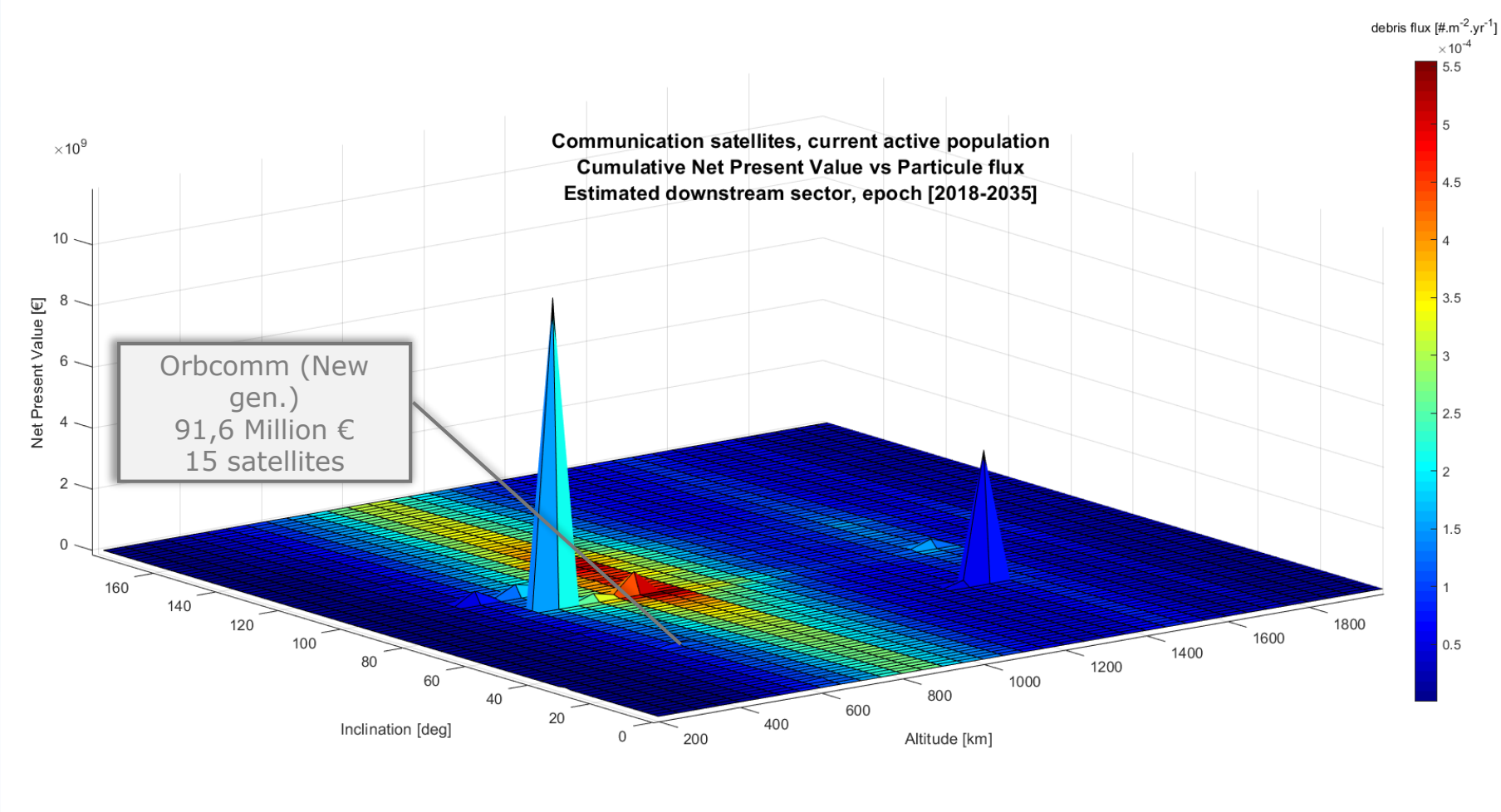


Results for communications satellites



Results for communications satellites



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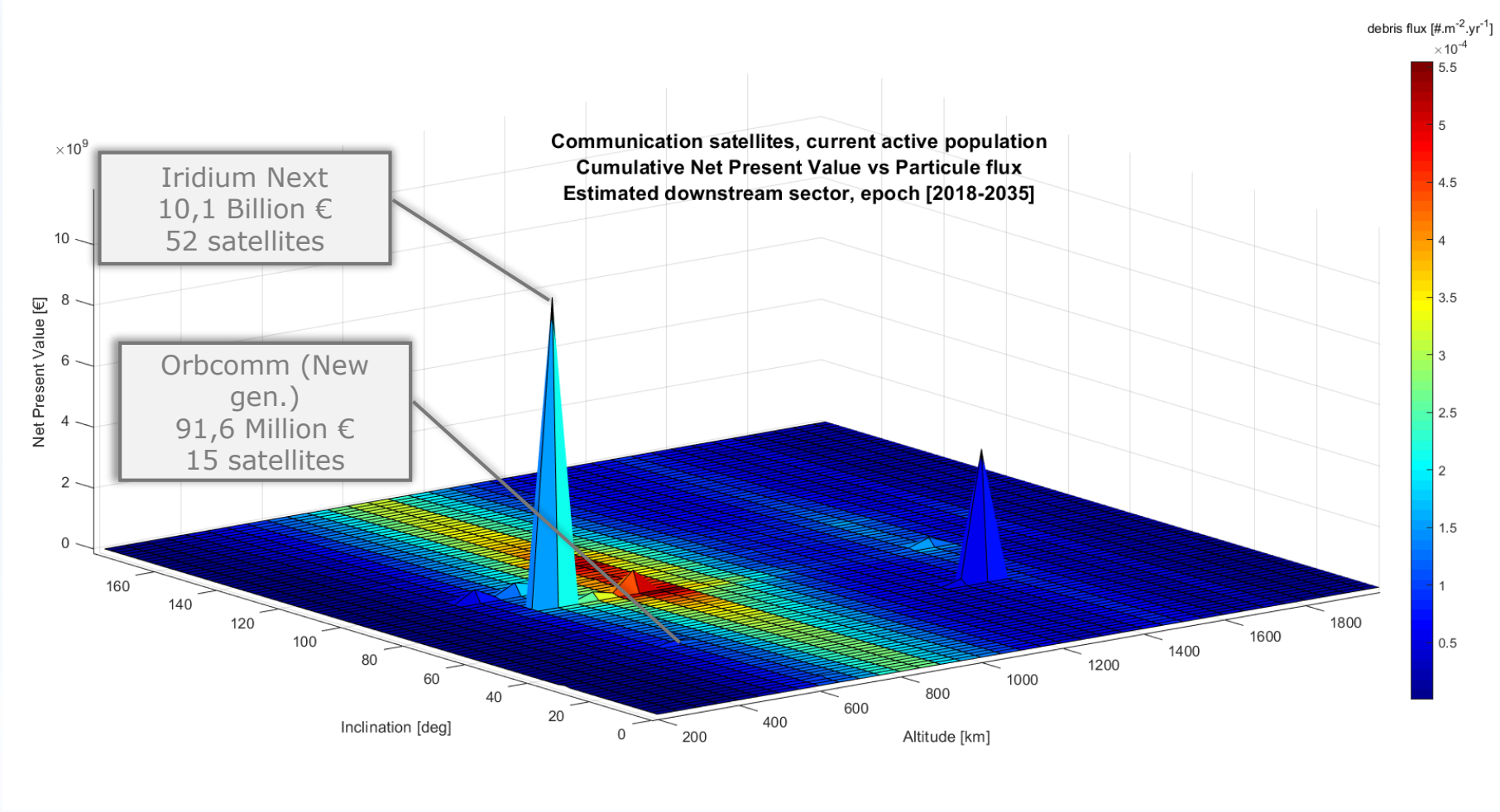

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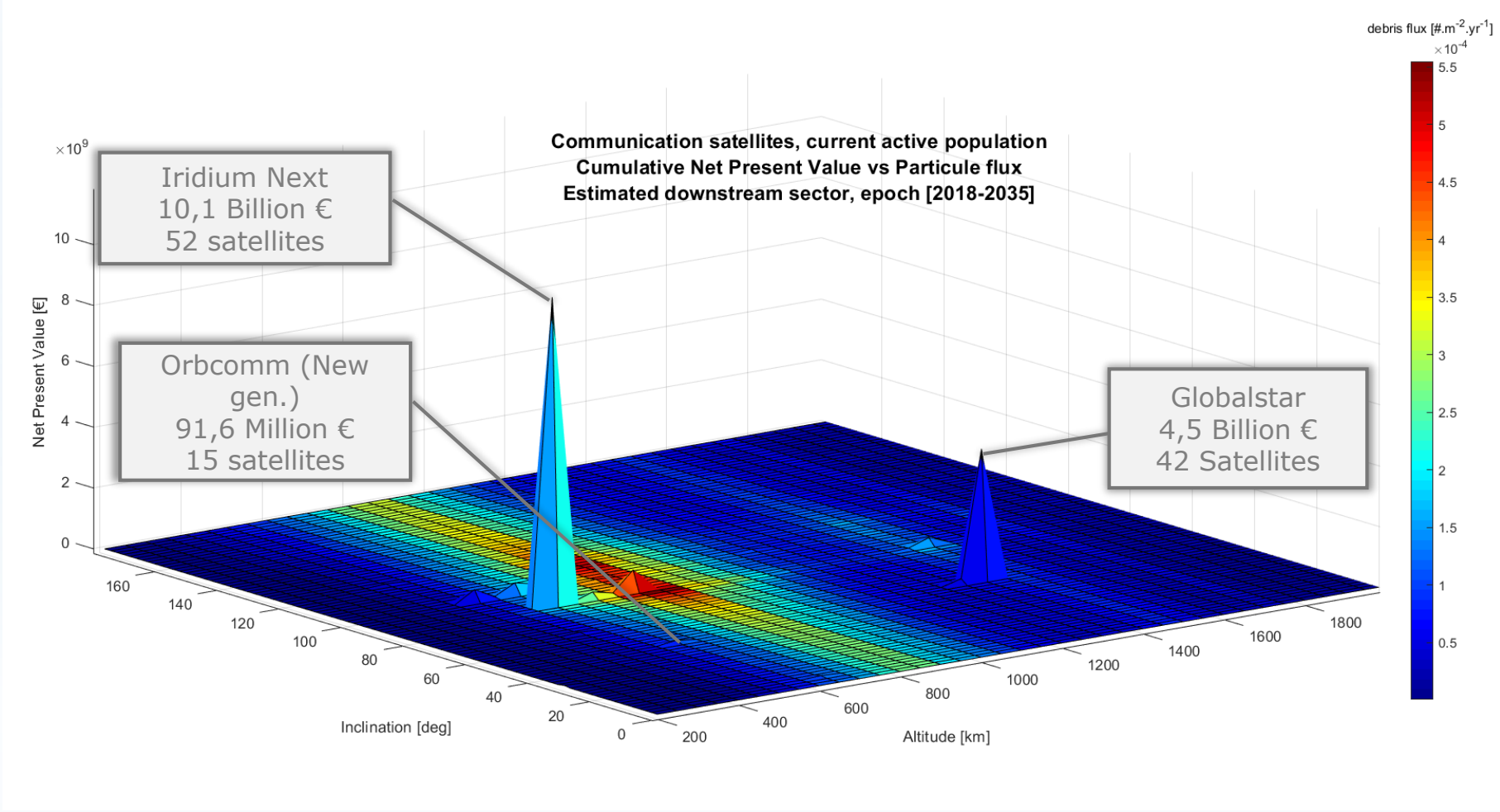

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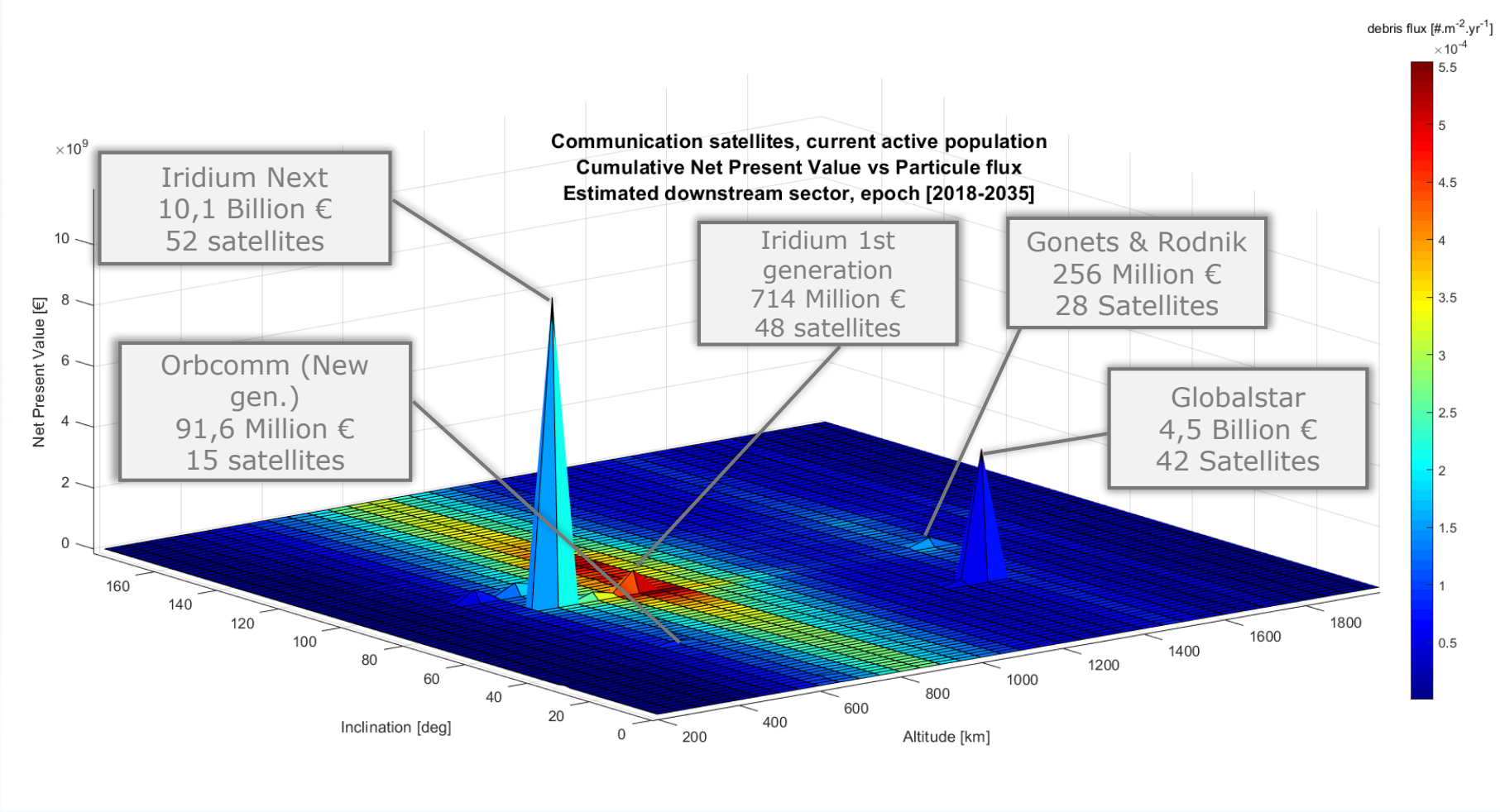

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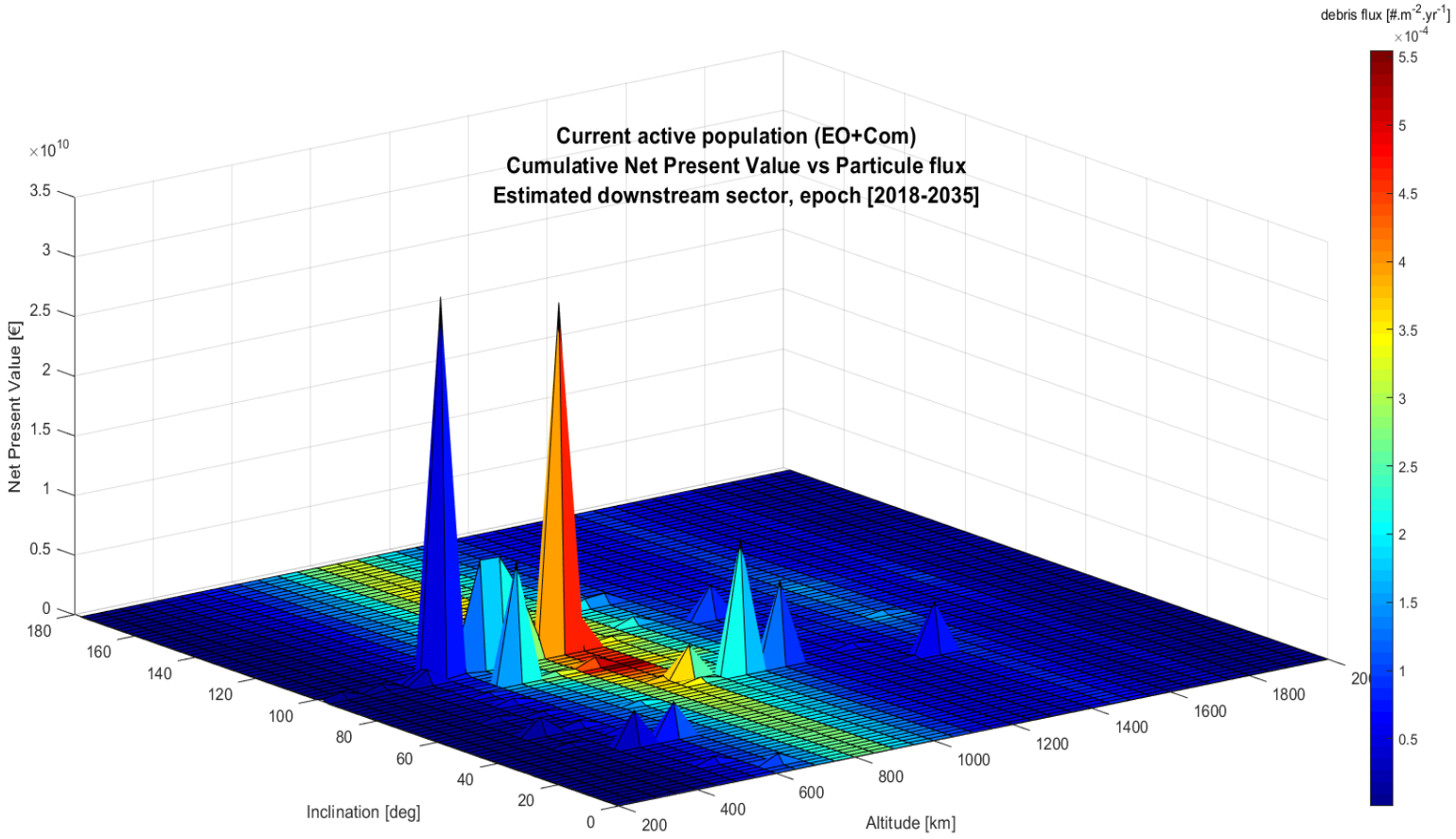
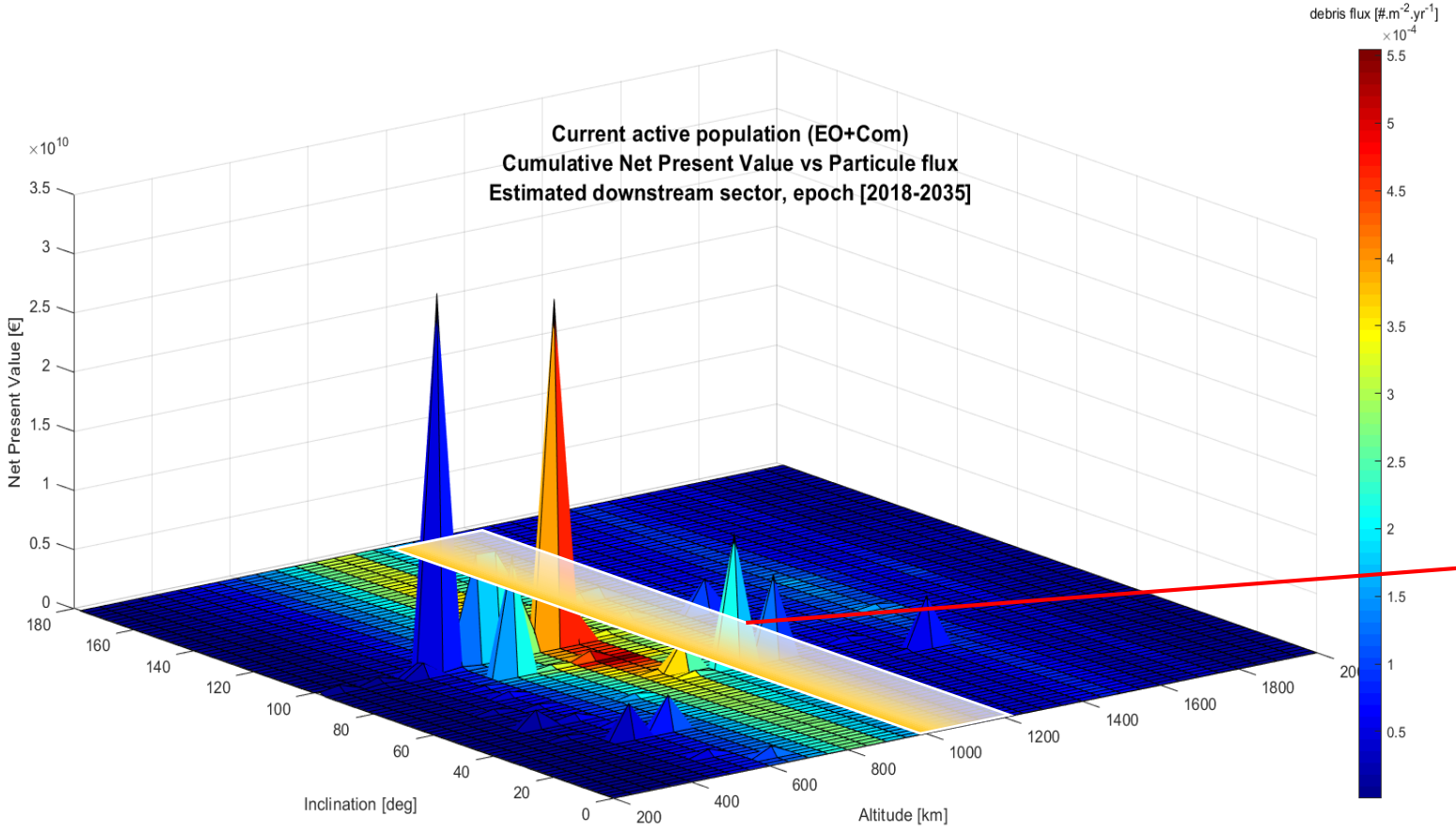

Current active population (EO+Com)
Cumulative Net Present Value vs Particule flux
Estimated downstream sector, epoch [2018-2035]
Net Present Value [€]
×10^10
3.5
3
2.5
2
1.5
1
0.5
0
Inclination [deg]
180
160
140
120
100
80
60
40
20
0
Altitude [km]
200
400
600
800
1000
1200
1400
1600
1800
debris flux [#.m^-2.yr^-1]
×10^-4
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5

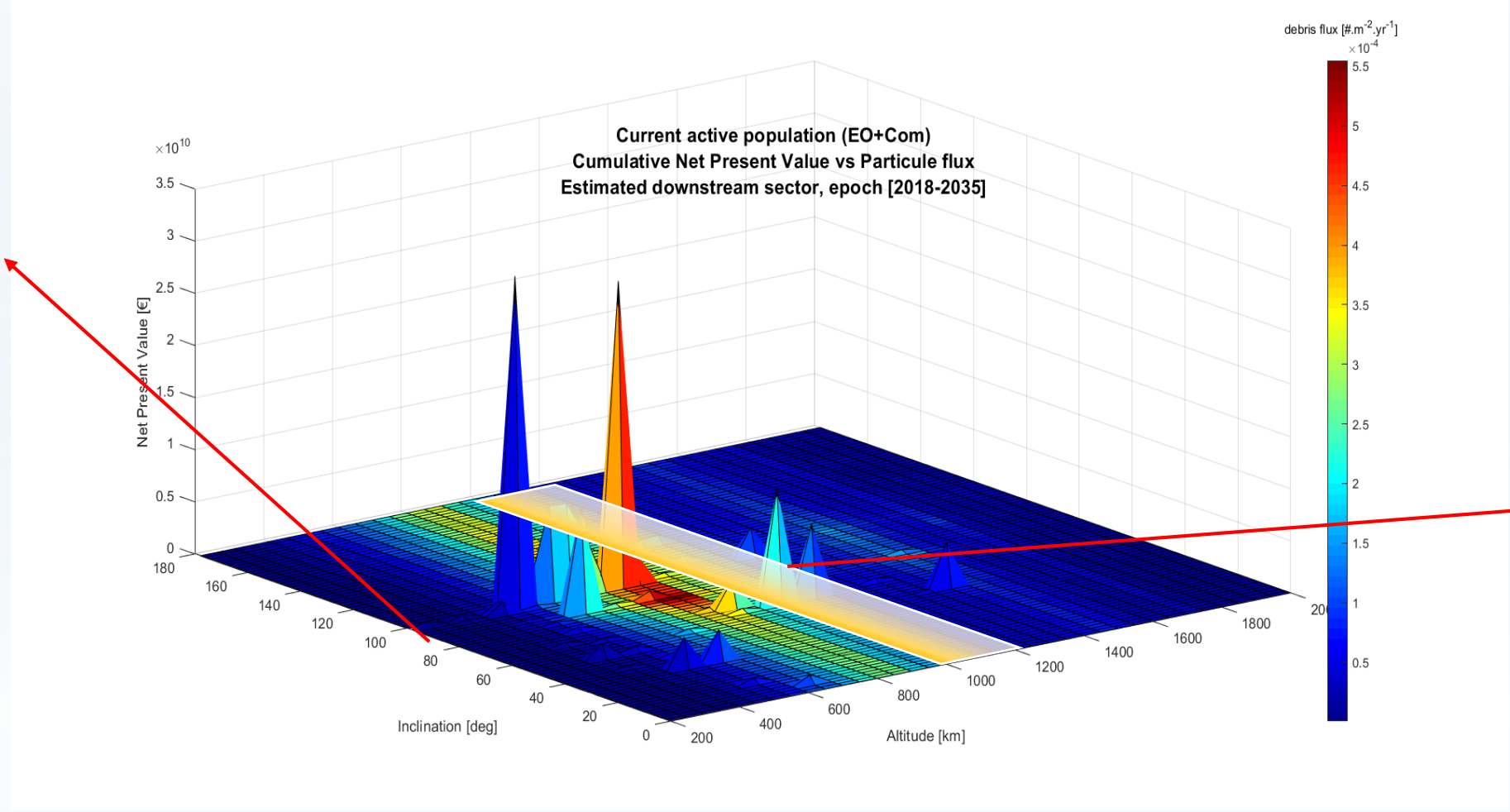
Results



Orbital band for future constellations

Results

82 and 98 degrees : Highlight inclined orbit



Orbital band for future constellations

6. Discussion & Take-Home message

Discussion

- Completeness of the scope: 77% of active satellites, LEO

- Scientific robustness:
  - Reliability of the input data (UCS database)
  - Life time estimated
  - Extension of WMO score (186 satellites covered → 451 estimated value)
  - Share of the end-user benefits in the overall value chain .

- First attempt to extend the valuation

Take-home message

- Economic valuation in compliance with LCA framework is proposed (final social-economic damage could be addressed)
- Few areas of the LEO region are valuable. However, the latter concentrate the majority of services for human activities.
- Most of Earth observation European satellites, with high value, are in the most crowded region of space. (SSO)
- Scope of the previous studies is enlarged : 75% of active satellites of LEO regions are value.

Thanks for your attention