

# How do errors in box-wing model propagate in a global GNSS solution

Pascal Stebler<sup>1</sup>, Maciej Kalarus<sup>1</sup>, Rolf Dach<sup>1</sup>, Erik Schönemann<sup>2</sup>, Adrian Jäggi<sup>1</sup>

<sup>1</sup>*Astronomical Institute of the University of Bern*

<sup>2</sup>*ESA/ESOC - Navigation Support Office*

IGS Symposium & Workshop, July 1, 2024 in Bern

# Outline

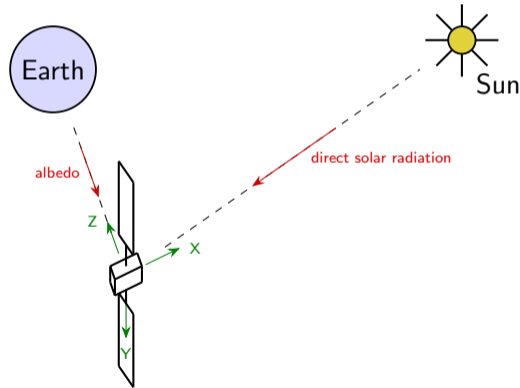
---

Introduction

Results on superposability of single surface modifications

Summary and Outlook

- This study was about **simulating** effects of erroneously modeled **radiation pressure** forces on **Galileo satellite orbits**.

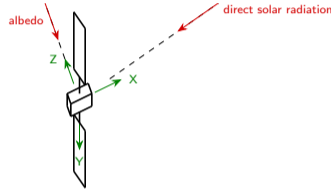




- The project was related to a subcontract with **Airbus Defence & Space** as part of a contract with **ESA**.
- ESA is mainly interested in the results related to **Galileo**.
- However, the results of this study are valid for **all box-wing MEO** satellites,
  - assuming an IGS style processing, e.g. not fixing station coordinates

# Radiation pressure model

- The **analytical radiation pressure model** used in this study was simplified to the **box-wing model** consisting only of
  - the **solar panels** and
  - **six surfaces** of the satellite body.



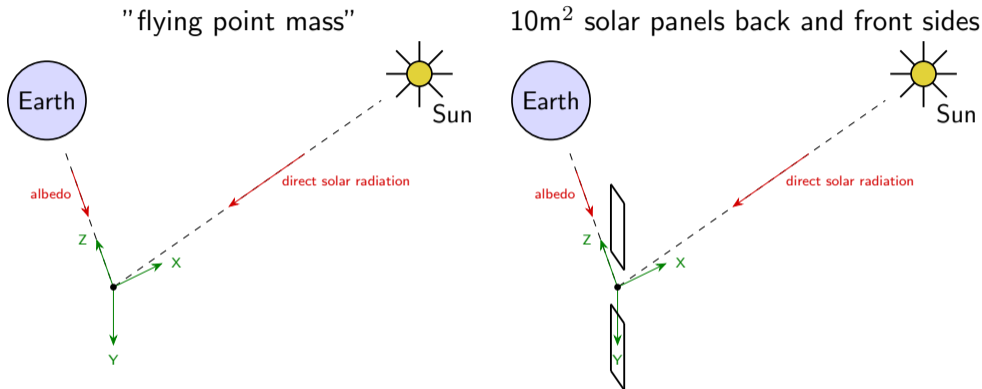
- Also the **optical properties** were simplified as usual into
  - infrared and visual part, as well as
  - absorption, diffuse reflection, and specular reflection.
- In addition, the empirical radiation pressure model **ECOM2** was used.

# Simplification of study cases

---

- Changing the area of a surface or its optical properties creates effects which are **correlated**,
- such that the interpretation of the simulations can get challenging.
- We therefore **disentangled** the simulations by defining single surfaces to be either fully absorbing (solar panels), fully specular reflecting or fully diffuse reflecting.
- We then compare **large single surface pairs** against a "flying point mass".

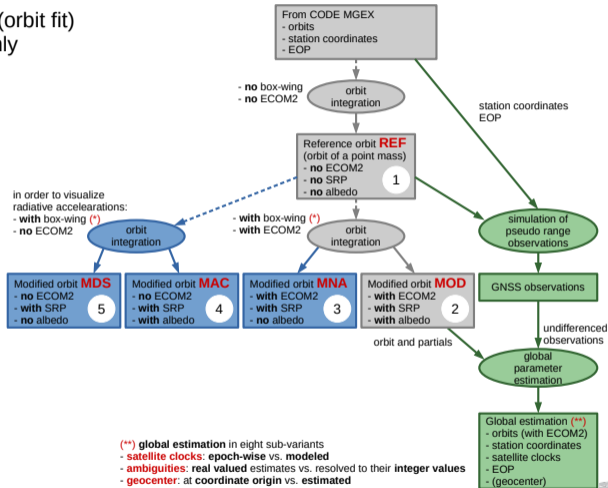
# Simplification of study cases



- We **also** simulate non-physical **single sided surfaces**.
- Since we expect only moderate changes of the orbit, the effects might then be **scaled and superposed**.

# Simulation scheme

**blue:** orbit integration only (orbit fit)  
**green:** global estimation only  
**gray:** both



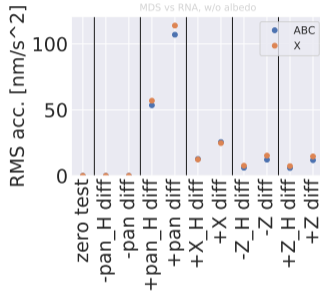


# Superposability of single surface modifications

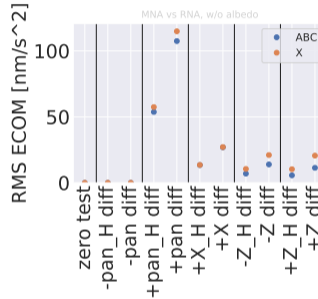
- The main results of this study are about the impact of **mismodeled single optical surfaces** on the orbit.
- From these results, we also would like to **mimic more general modifications** in the analytical box-wing model by **superposing the results** for single optical surfaces.
- The following slides highlight this latter aspect.

# Linearity

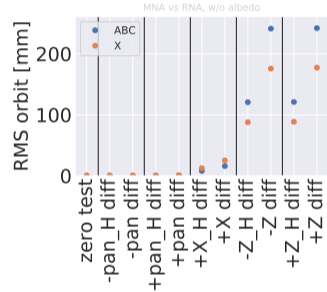
"5-1": rad. press. acc.



"3-1": ECOM2



"3-1": orbit



- 10m<sup>2</sup> solar panels, 3m<sup>2</sup> X, and 3m<sup>2</sup> Z surfaces
- Overall RMS [mm] of the differences relative to the reference orbit
- Check if 2 times result of half area corresponds to full area

# Extended CODE orbit model ECOM2

- **Modeled acceleration** due to radiation pressure:

$$\vec{a}_{rpr}(\text{du}) = D(\text{du})\vec{e}_D + Y(\text{du})\vec{e}_Y + B(\text{du})\vec{e}_B$$

- **Parametrization** of  $D(\text{du})$ ,  $Y(\text{du})$  and  $B(\text{du})$ :

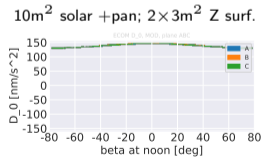
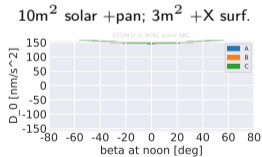
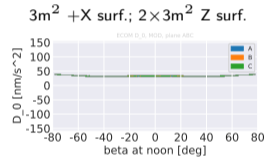
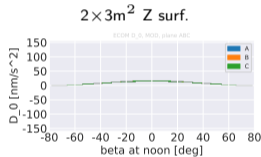
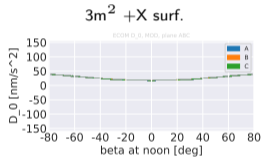
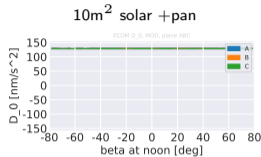
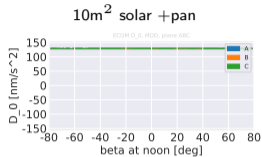
$$D(\text{du}) = D_0 + D_{C2} \cos(2\text{du}) + D_{S2} \sin(2\text{du})$$

$$Y(\text{du}) = Y_0$$

$$B(\text{du}) = B_0 + B_{C1} \cos(\text{du}) + B_{S1} \sin(\text{du})$$

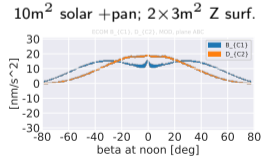
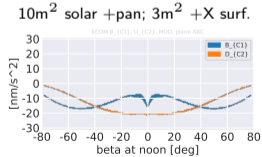
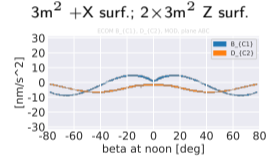
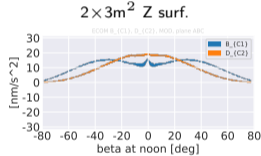
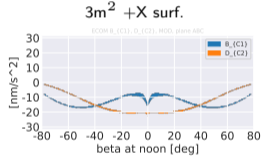
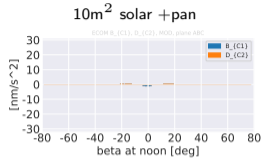
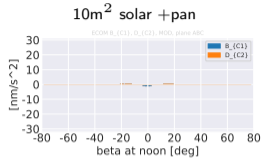
- $\text{du}$ : difference  $u_{\text{sat}} - u_{\text{Sun}}$
- ECOM, Beutler et al., 1994, ECOM2, D. Arnold et al., 2015

# Combining box-wing surfaces, scale $150 \text{ nm/s}^2$



- SRP with albedo, fully specular reflection, ECOM2 term D<sub>0</sub>

# Combining box-wing surfaces, scale $30 \text{ nm/s}^2$



- SRP with albedo, fully specular reflection, ECOM2 terms  $B_{C1}$  and  $D_{C2}$

# Summary

---

- We analysed the impact of **mismodeled individual box-wing surfaces** on
  - the **reintegrated orbits** (simulation part)
  - and on **global estimations** (results not presented today).
- The **deficiencies** are **absorbed** by the ECOM2 parameters to a large extent.
- It seems to be **reasonable to superpose** the results of **single surface modifications** in order to **mimic more complex modifications** of the analytical box-wing model.
- A corresponding paper will follow.

# Outlook

---

- **Analyze IGS Final** data products in order to search for **patterns** found in this study.

Thanks a lot for your attention!