

# PyKEP 3: A coolbox for interplanetary trajectory design

Dario Izzo<sup>1</sup> and Francesco Biscani<sup>2</sup>

<sup>1</sup> European Space Agency's Advanced Concepts Team, The Netherlands <sup>2</sup> European Space Agency's Advanced Concepts Team, The Netherlands

DOI: [10.xxxxxx/draft](https://doi.org/10.xxxxxx/draft)

## Software

- Review [↗](#)
- Repository [↗](#)
- Archive [↗](#)

Editor: [Open Journals](#) [↗](#)

## Reviewers:

- [@openjournals](#)

Submitted: 01 January 1970

Published: unpublished

## License

Authors of papers retain copyright and release the work under a Creative Commons Attribution 4.0 International License ([CC BY 4.0](#)).

## Summary

PyKEP 3 is a Python toolbox developed at the [European Space Agency](#) by the [Advanced Concepts Team](#) to perform quick analysis of interplanetary trajectory design problems. It is designed to be used by researchers and engineers to prototype and test new ideas in the field of astrodynamics. The library provides efficient implementations of algorithms for solving the multiple revolutions Lambert's problem, low-thrust problems, multiple asteroid rendezvous problems, and more. It also provides support for [JPL SPICE](#), SGP4 propagation, and the [Heyoka](#) Taylor integration suite.

## Introduction

PyKEP 3 is the third iteration of the PyKEP library, which has been used by the [Advanced Concepts Team](#) at the European Space Agency for over a decade. The library was originally developed to support the participation of non astrodynamics experts in the [Global Trajectory Optimization Competition](#) and has since grown into a generic tool for the preliminary analysis of interplanetary trajectory design problems. Previous versions of the code were used internally to perform some preliminary analysis for the design of the [Hera mission](#), the M-ARGO interplanetary cubesat concept, the preliminary analysis of the the initial concepts for the Titan and Enceladus Mission (TandEM) as well as the Laplace mission. At the core of the library are the necessary building blocks to perform preliminary analysis of interplanetary trajectory design problems, with the aim to provide the general scientific community with a tool to prototype and test new ideas in the field of astrodynamics focussing on novel ideas rather than on the implementation of the basic algorithms. Most techniques implemented in the library are largely based on original research performed at the ACT, as well as on the state-of-the art algorithms available from the literature. A Lambert solver as well as low-thrust optimization algorithms (both based on direct and indirect methods) are available together with a number of approximate methods to estimate transfer costs. The library interfaces to a number of open source projects providing relevant functionalities including [spicepy](#) for interfacing to JPL SPICE, [SGP4](#) to get standard Low Earth Orbit orbits, [Heyoka](#) to perform efficient Taylor integration and [pygmo](#) to interface to state-of-the art optimization routines.

## Mathematics

Single dollars (\$) are required for inline mathematics e.g.  $f(x) = e^{\pi/x}$

Double dollars make self-standing equations:

$$\Theta(x) = \begin{cases} 0 & \text{if } x < 0 \\ 1 & \text{else} \end{cases}$$

37 You can also use plain  $\LaTeX$  for equations

$$\hat{f}(\omega) = \int_{-\infty}^{\infty} f(x) e^{i\omega x} dx \quad (1)$$

38 and refer to [Equation 1](#) from text.

## 39 Citations

40 Citations to entries in paper.bib should be in [rMarkdown](#) format.

41 If you want to cite a software repository URL (e.g. something on GitHub without a preferred  
42 citation) then you can do it with the example BibTeX entry below for Smith et al. ([2020](#)).

43 For a quick reference, the following citation commands can be used: - @author:2001 ->  
44 "Author et al. (2001)" - [@author:2001] -> "(Author et al., 2001)" - [@author1:2001;  
45 @author2:2001] -> "(Author1 et al., 2001; Author2 et al., 2002)"

## 46 Figures

47 Figures can be included like this: Caption for example figure. and referenced from text using  
48 [section](#) .

49 Figure sizes can be customized by adding an optional second parameter: Caption for example  
50 figure.

## 51 Acknowledgements

52 We acknowledge contributions from .... and support from ...

## 53 References

54 Smith, A. M., Thaney, K., & Hahnel, M. (2020). Fidgit: An ungodly union of GitHub and  
55 figshare. In *GitHub repository*. GitHub. <https://github.com/arfon/fidgit>