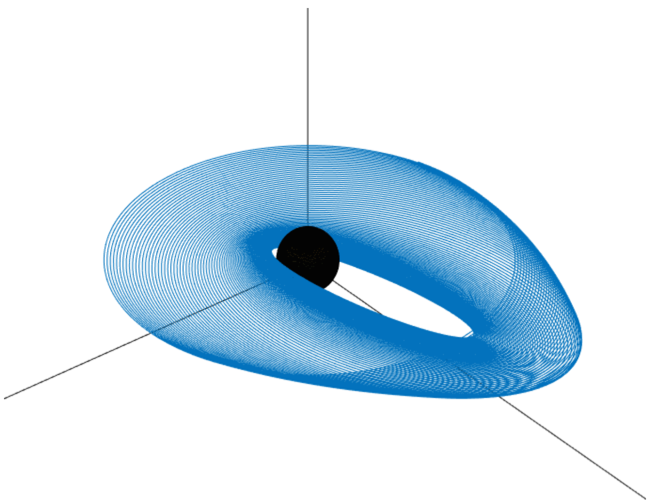
A Sequential Method to Compute Multiobjective Optimal Low-Thrust Earth Orbit Transfers



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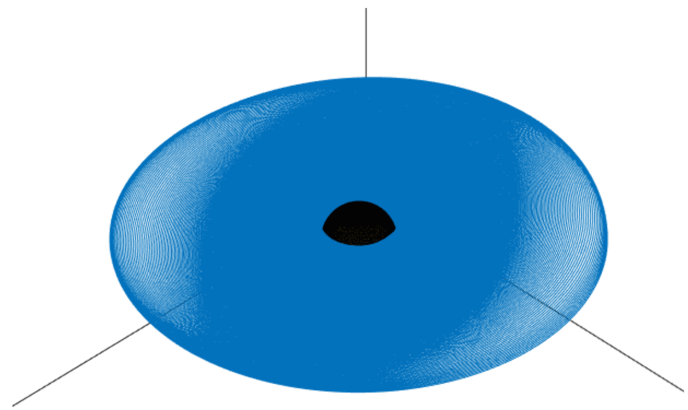

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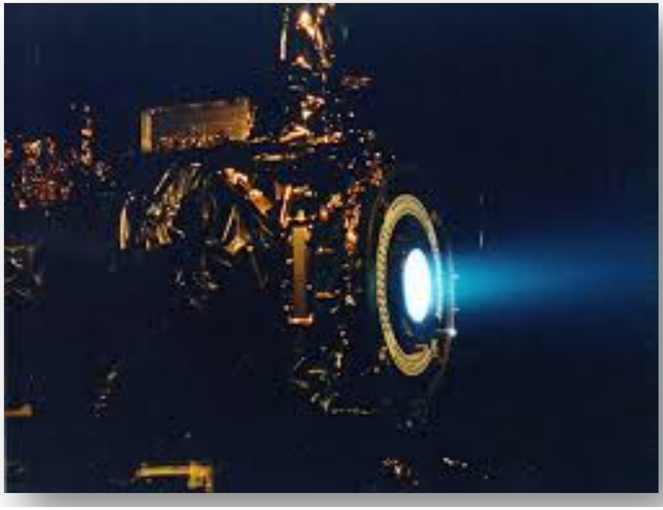
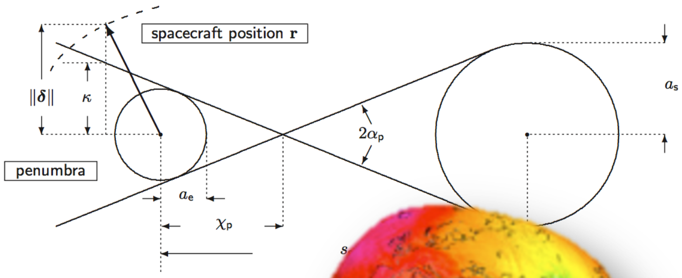
OUTLINE

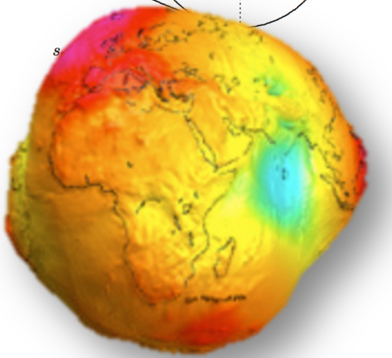
① INTRODUCTION.
② OPTIMAL HYBRID CONTROL PROBLEM.
③ SEQUENTIAL ALGORITHM.
④ NUMERICAL RESULTS.
⑤ CONCLUSIONS.
⑥ FUTURE WORK.

MOTIVATION

- Propellant savings.
- Maturity and reliability for EP systems: NASA Deep Space 1 and ESA SMART 1.
- All-electric satellite in GEO.







PROBLEMS

- T / W << 1 (Large times)
- Perturbations have an amplified impact (Oblateness, Third body …).
- Earth-Shadow effect.

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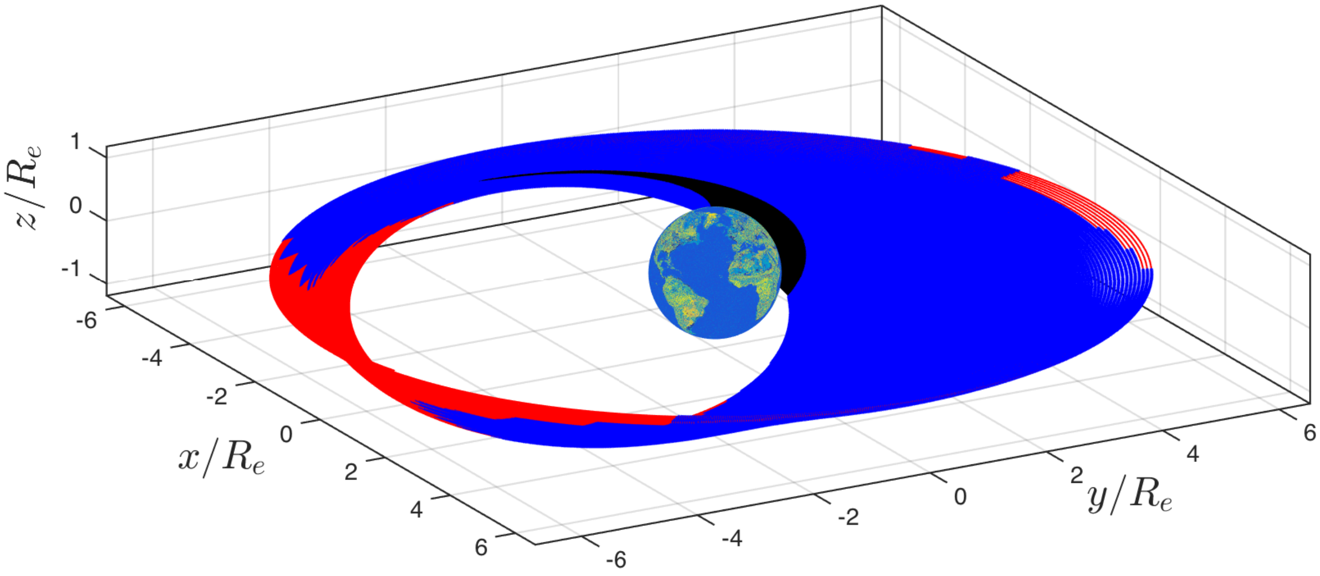
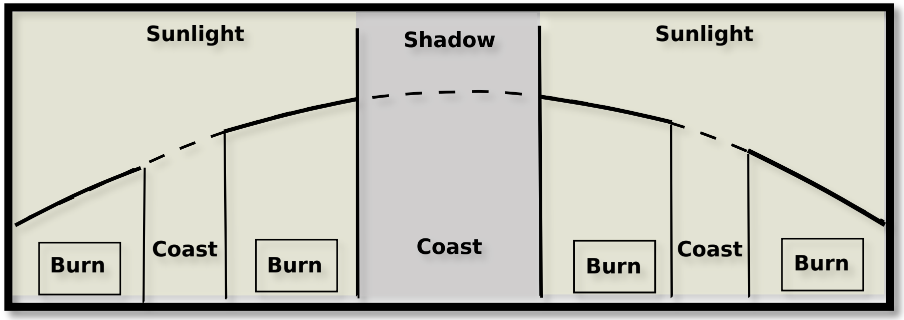
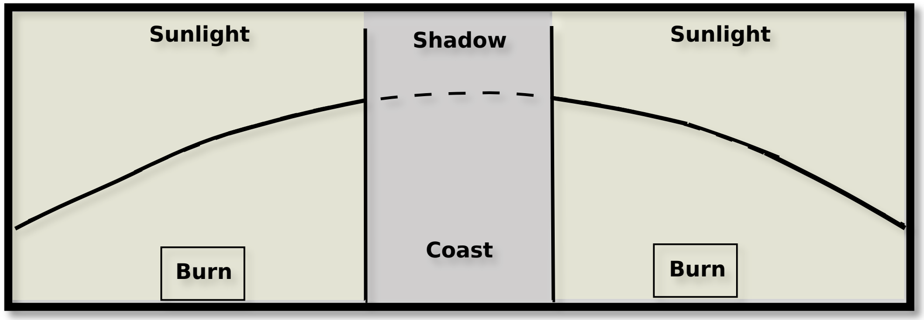




MINIMUM-FUEL



MINIMUM-TIME

2. HYBRID OPTIMAL CONTROL PROBLEM

HYBRID OPTIMAL CONTROL PROBLEM

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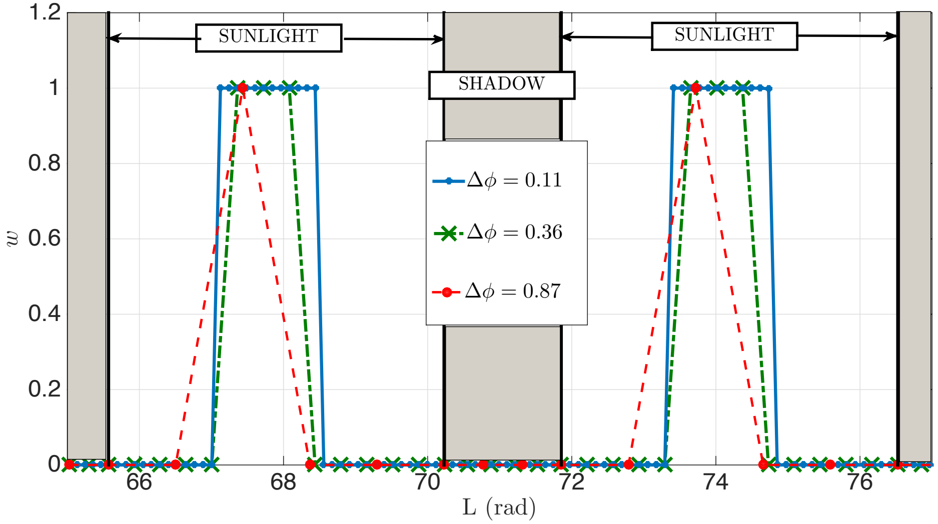
MIXED INTEGER OPTIMAL CONTROL PROBLEM

↓

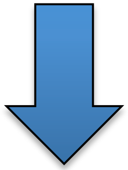
CLASSICAL OPTIMAL CONTROL PROBLEM

↓

DIRECT COLLOCATION METHOD



YANG GAO



NLP

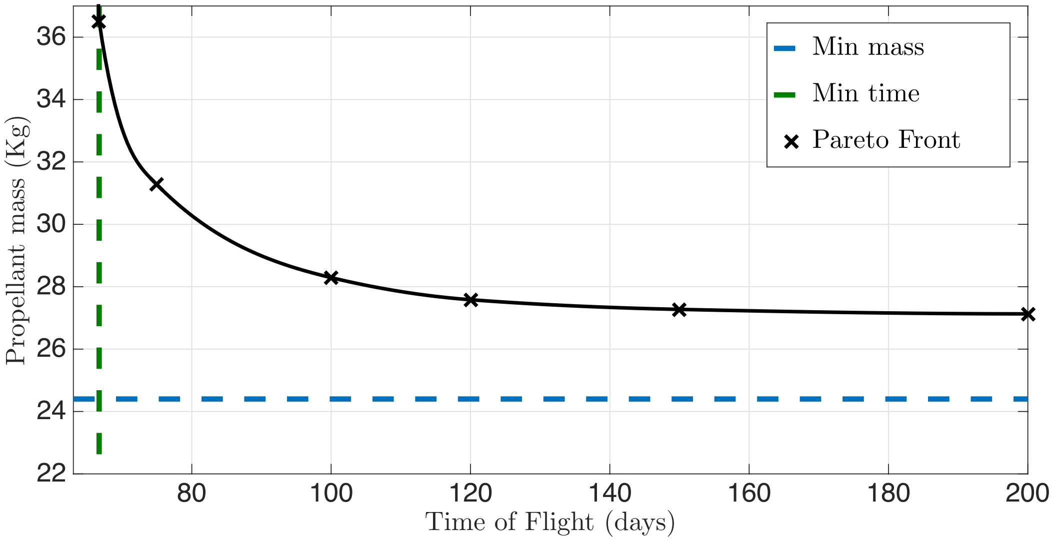
$$n_k = \frac{L_{k+1,1} - L_{k,1}}{2\pi} \left| \frac{||\bar{r_k}|| - ||\bar{r}||}{||\bar{r}||} \right| \mathcal{N}$$

GTO-GEO TEST CASE

Orbits	a/R_e	e	i (deg)	Ω (deg)	ω (deg)
GTO	3.820	0.731	27	99	0
GEO	6.6107	10^{-4}	10^{-4}	–	–

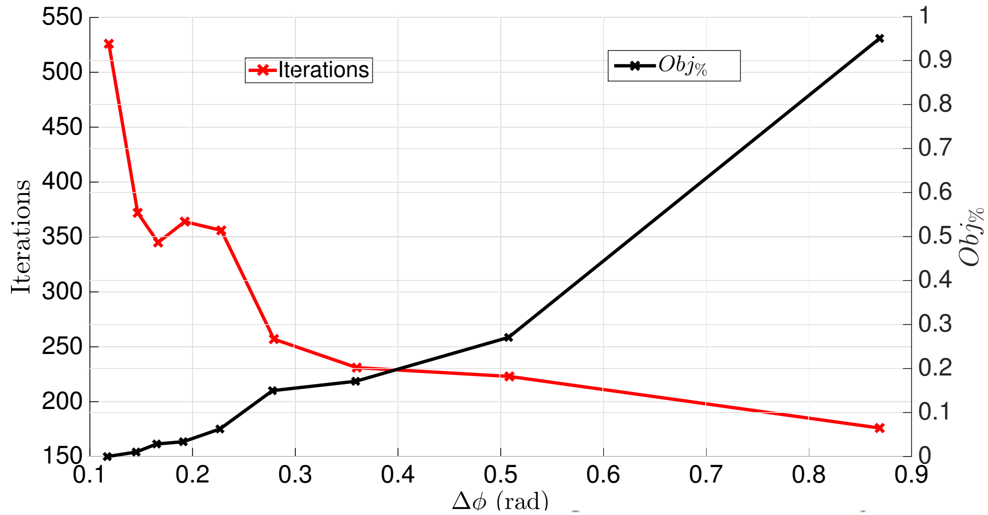
SPACECRAFT PARAMETERES

P (kW)	$I_{sp}(s)$	η	m_0 (kg)	$T/(m_0 g_0)$
5	3300	0.65	450	$4.55 \cdot 10^{-5}$



Transfer Time $(days)$					
66.7	75	100	120	150	200
Propellant mass (Kg)					
36.50	31.27	28.29	27.58	27.27	27.13

4. NUMERICAL RESULTS



k	$\Delta\bar{\phi}(rad)$	Obj.(kg)	Iter.	Variables	Constraints	CPU time(s)	ε_{min}	ε_{max}	ε_{3body}
1	0,8690	27,4910	176	19829	15971	188,03	0,1584	0,6028	0,6131
2	0,5085	27,3059	223	33885	26730	413,27	0,0710	0,3244	0,3359
3	0,3599	27,2787	231	47873	37445	601,58	0,0525	0,2211	0,2323
4	0,2792	27,2729	257	61928	48212	875,37	0.0409	0,1708	0,1821
5	0,2280	27,2492	346	75919	58924	1442,36	0,0316	0,1285	0,1549
6	0,1924	27.2414	364	89900	69632	1798,44	0,0311	0,1003	0,1282
7	0,1665	27,2399	345	103860	80319	1974,34	0,0268	0,0857	0,1127
8	0,1466	27,2350	372	117972	91134	2384,36	0,0241	0,0857	0,0992
9	0,1185	27,2322	526	145956	112563	4276,58	0,0201	0,0704	0,0824

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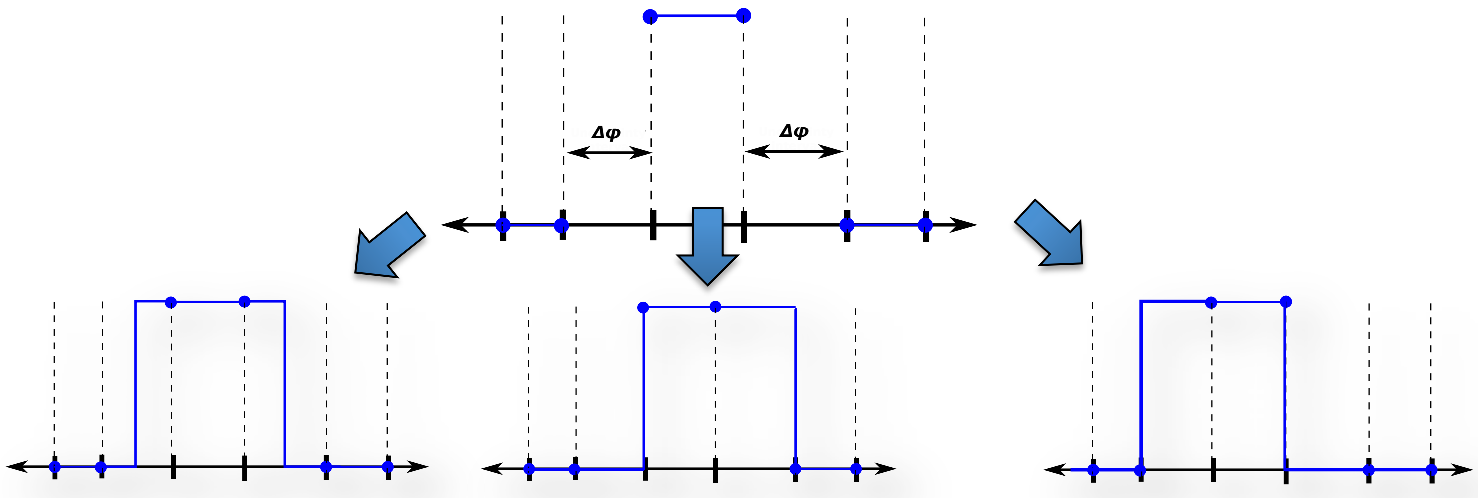

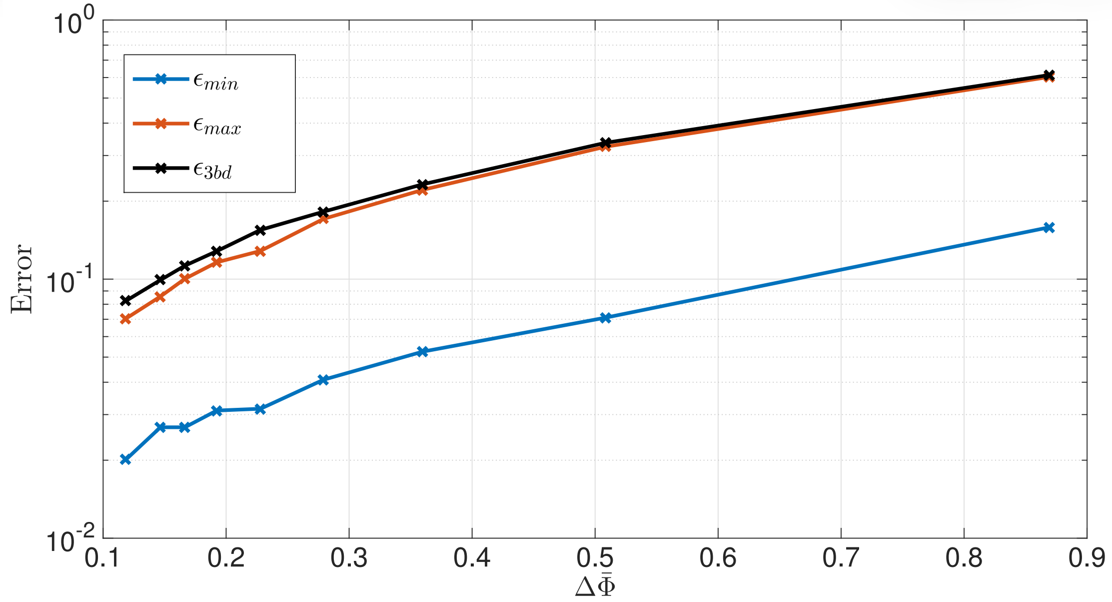

- A **sequential method** for solving the Low-thrust orbit transfer **HOCP** has been **successfully** implemented.
- It has been successfully applied to a GTO-GEO transfer problems.
- The method is:
- The suitability and applicability of the control law have been tested.
- This method will be **useful** for preliminary **mission design**.

- Apply this method to the **more complex scenario**
- Account for the suitability of the control law in a high fidelity dynamical system.
- The ultimate goal is to enhace flexibility according to detail-level requirements, to improve robistness and tho head for automatization in optiming low-thrust transfer trajectories.

Thank you for your attention.

Questions
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