National Aeronautics and Space Administration

Optimization of the Lunar IceCube Trajectory Using Stochastic Global Search and Multi-Point Shooting

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code 595

NAVIGATION & MISSION DESIGN BRANCH

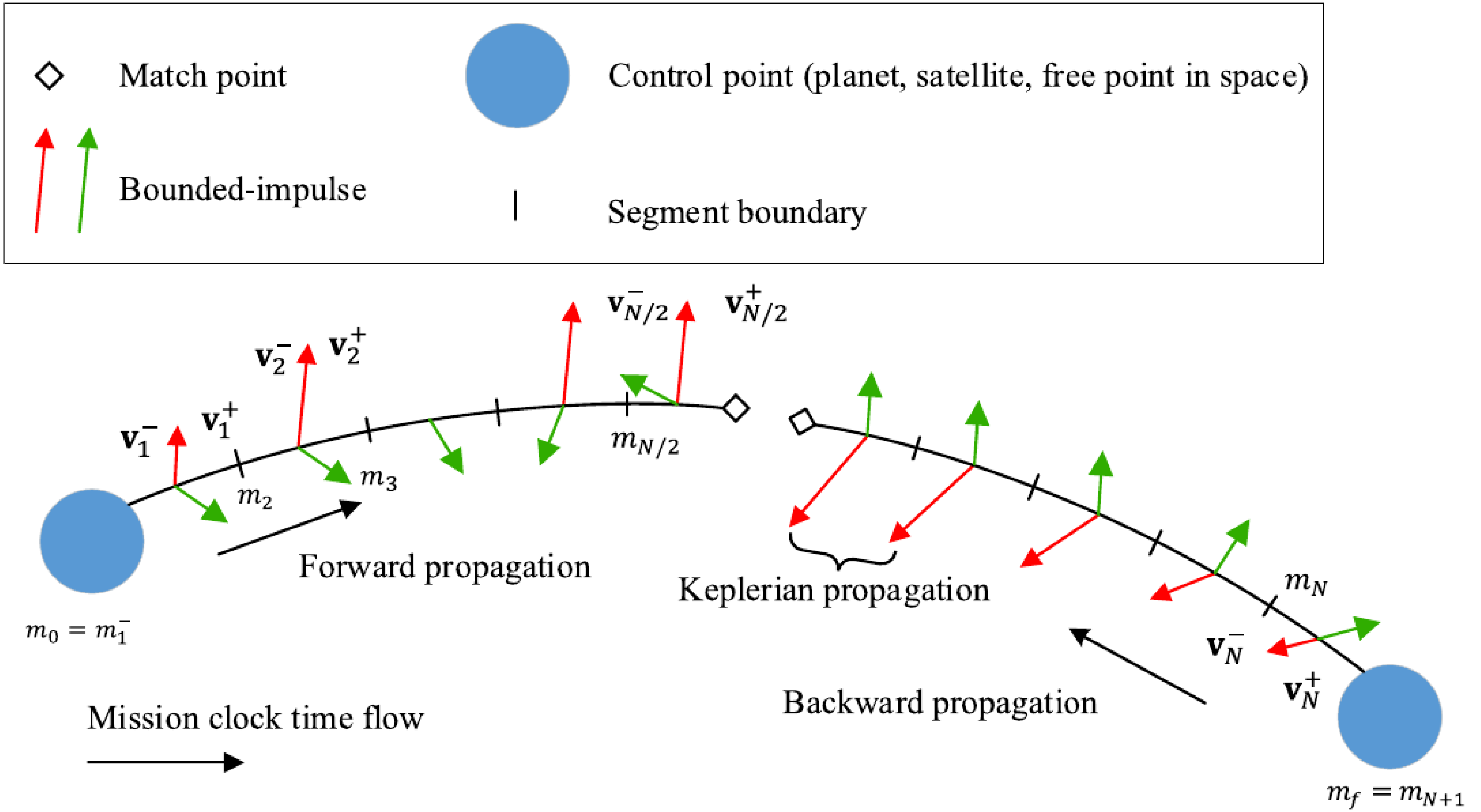
NASA GSFC

Agenda

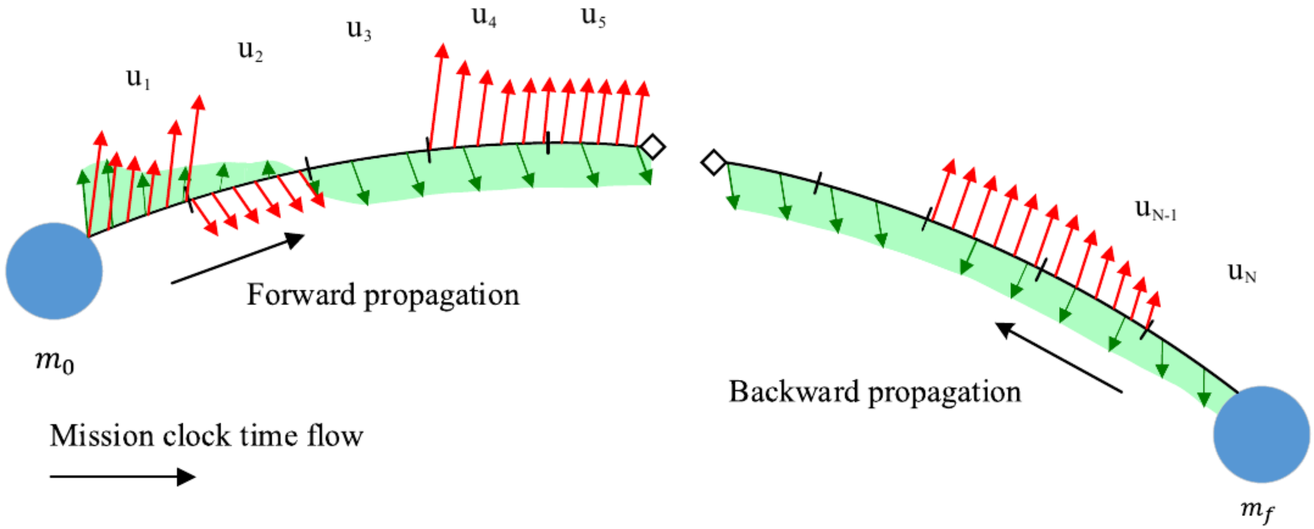
- Physical Model
- Optimization and Global Search
- ConOps and Problem Structure
- Examples

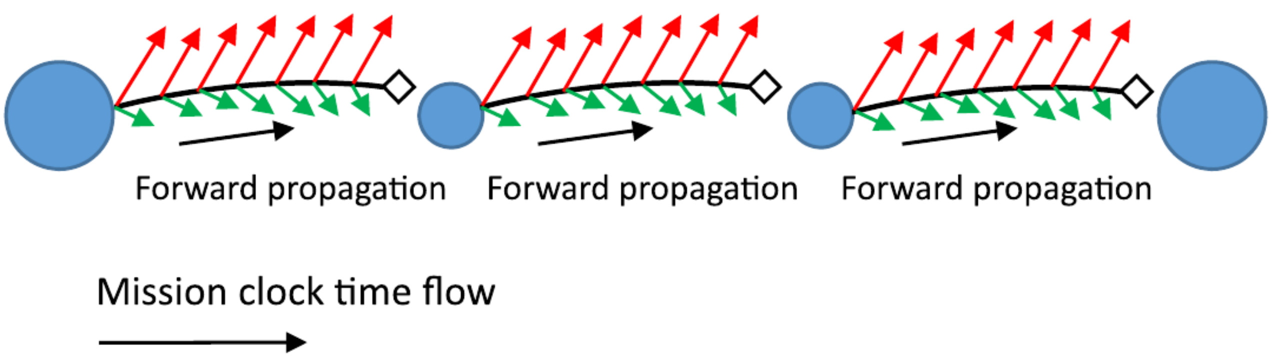
Physical Model

Low-Fidelity Analysis: Sims-Flanagan with Averaged *n*-Body Gravity

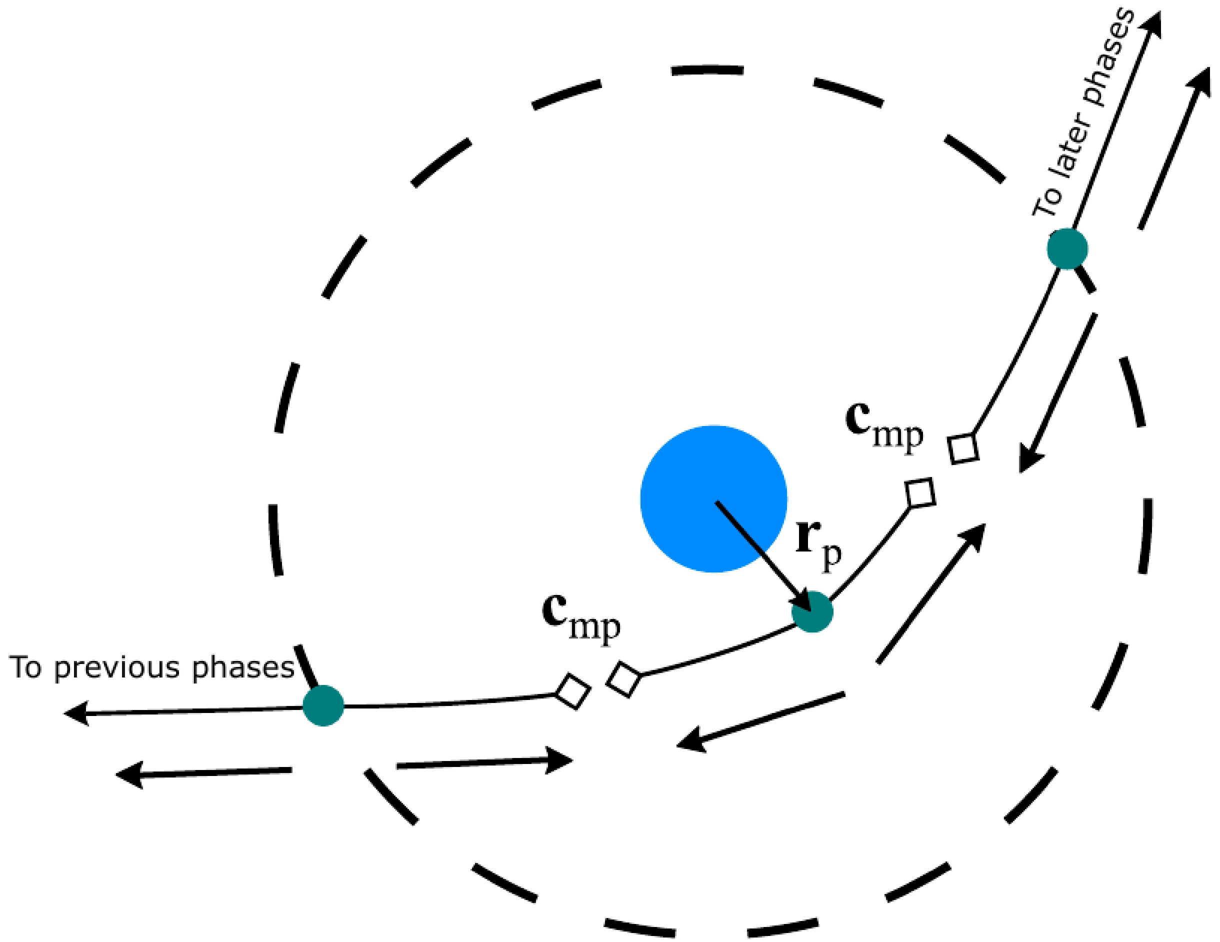


High-Fidelity Optimization via Direct Two-Point or Parallel Shooting





Lunar Gravity Assist



Optimization and Global Search

Inner-Loop Solver: Nonlinear Programming (NLP)

Minimize $f(\boldsymbol{x})$

Subject to:

$$\boldsymbol{x}_{lb} \leq \boldsymbol{x} \leq \boldsymbol{x}_{ub}$$
$$\boldsymbol{c}(\boldsymbol{x}) \leq \boldsymbol{0}$$
$$\boldsymbol{A}\boldsymbol{x} \leq \boldsymbol{0}$$

where:

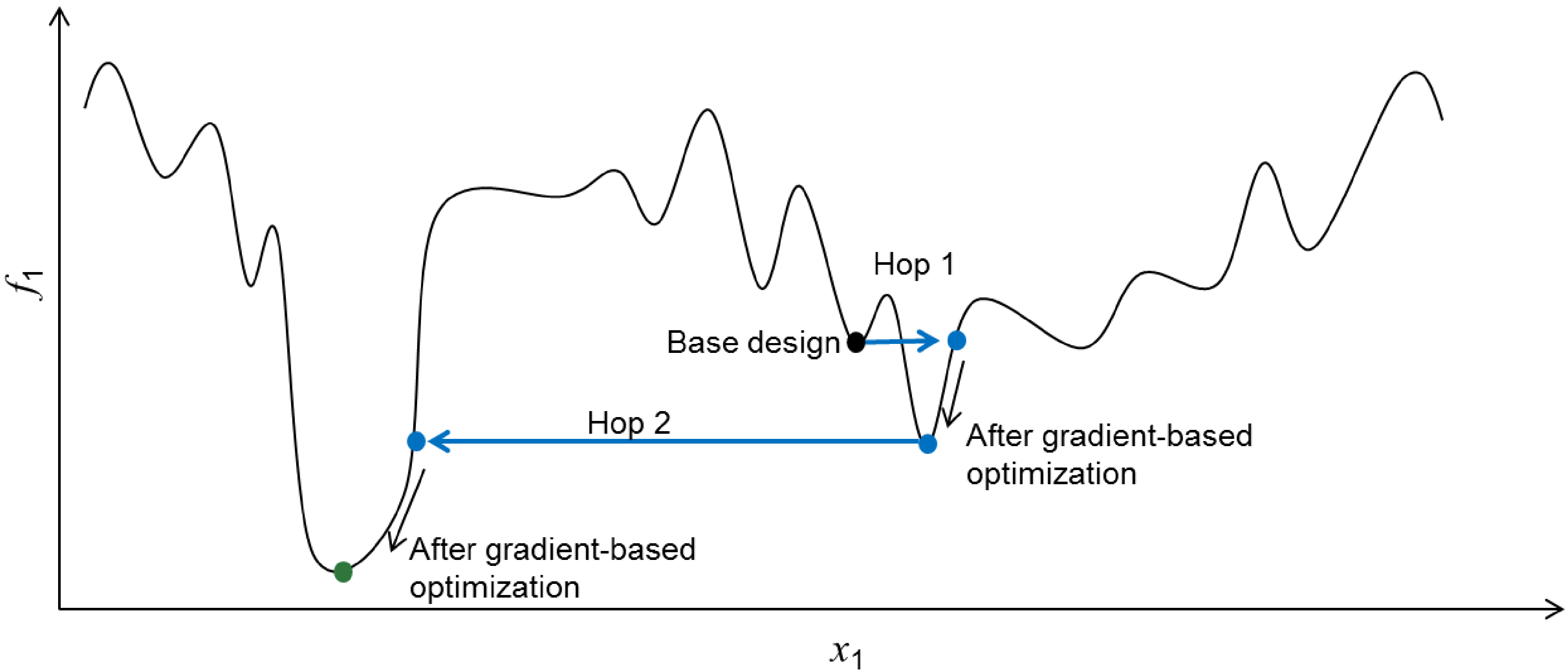
$\boldsymbol{x}_{lb}$, $\boldsymbol{x}_{ub}$ are lower and upper bounds on the decision variables

$\boldsymbol{c}(\boldsymbol{x})$ is a vector of nonlinear constraints

$\boldsymbol{A}\boldsymbol{x}$ is a vector of linear constraints

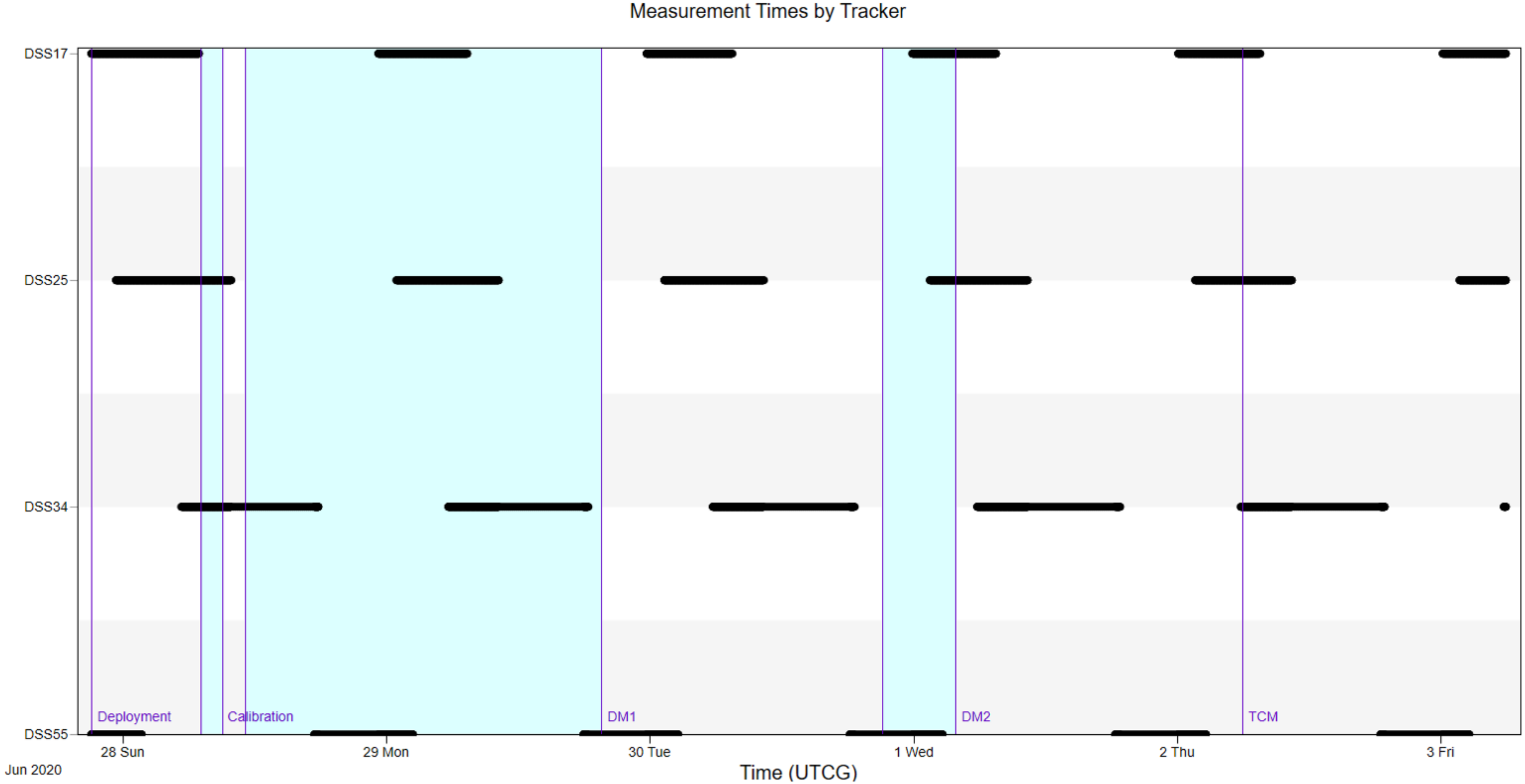
- We use the Sparse Nonlinear OPTimizer (SNOPT)
- Analytical expressions are provided for every element of the Jacobian
- But all NLP problem solvers require an initial guess…

Inner-Loop Solver:
Monotonic Basin Hopping (MBH)

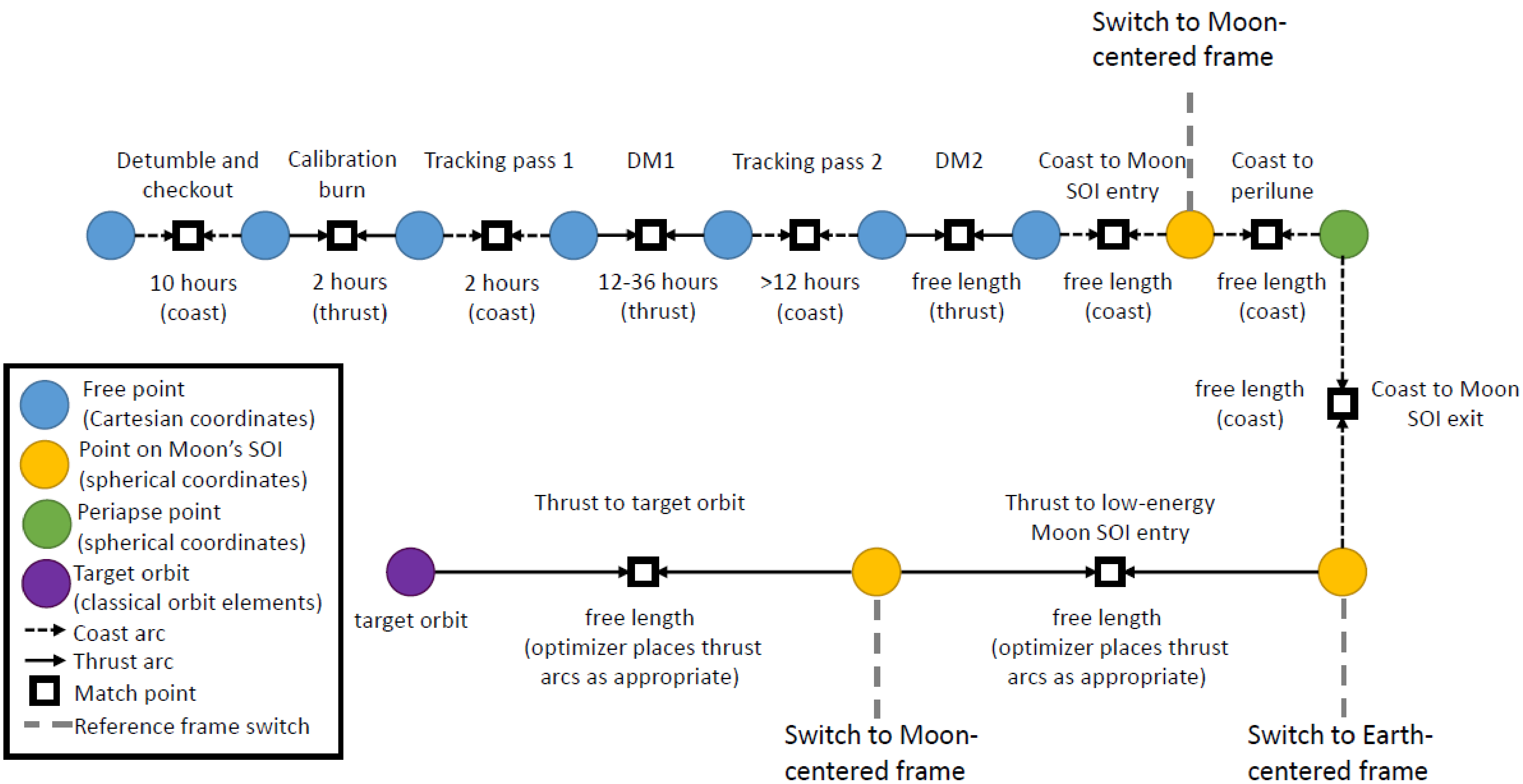


ConOps and Problem Structure

Deployment to LGA

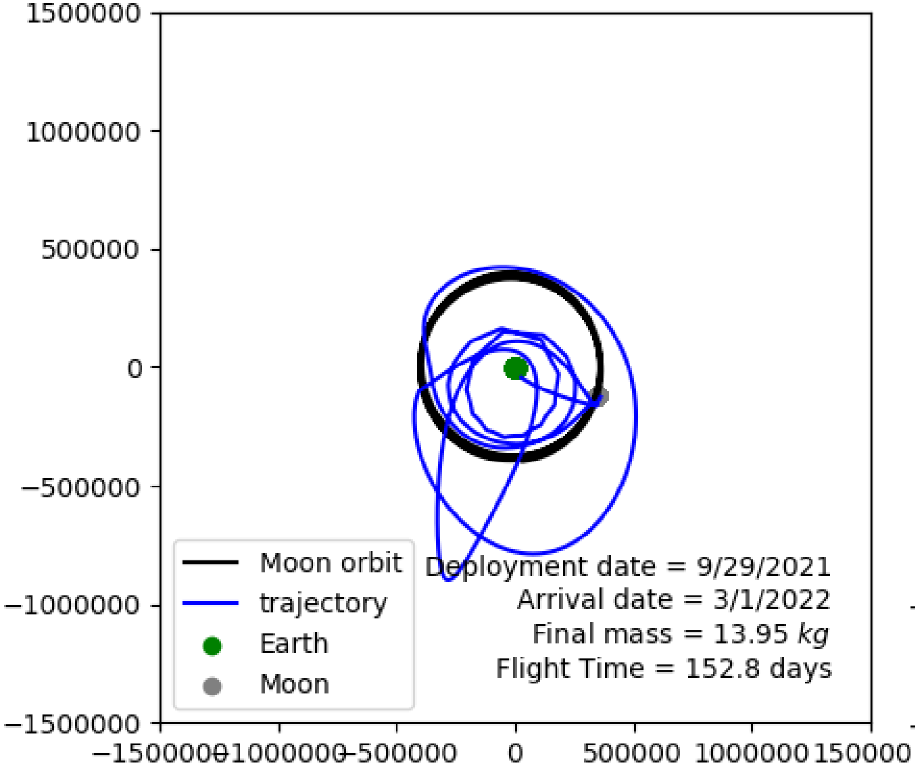


Lunar IceCube as an Optimization Problem

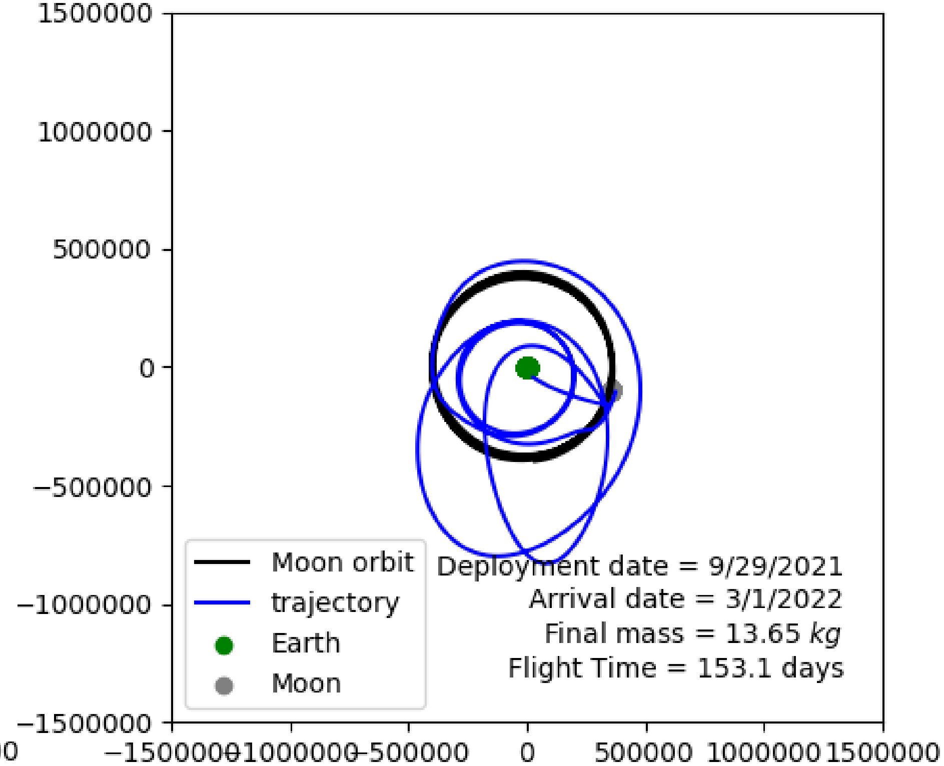


Examples

Low-Fidelity vs High-Fidelity Point Solution



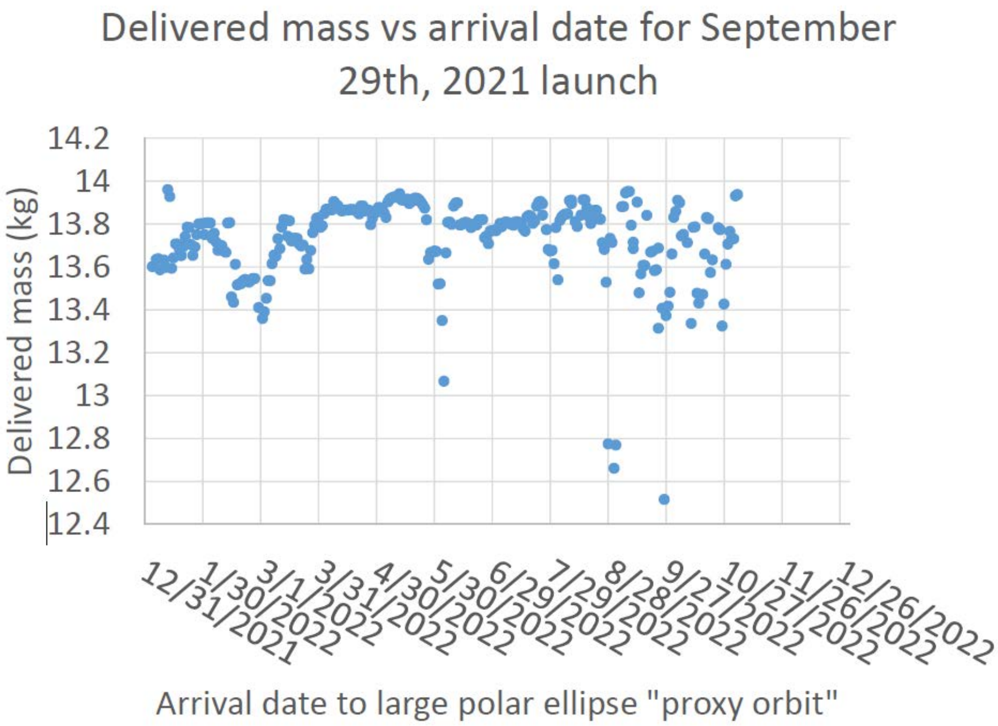
Low-Fidelity

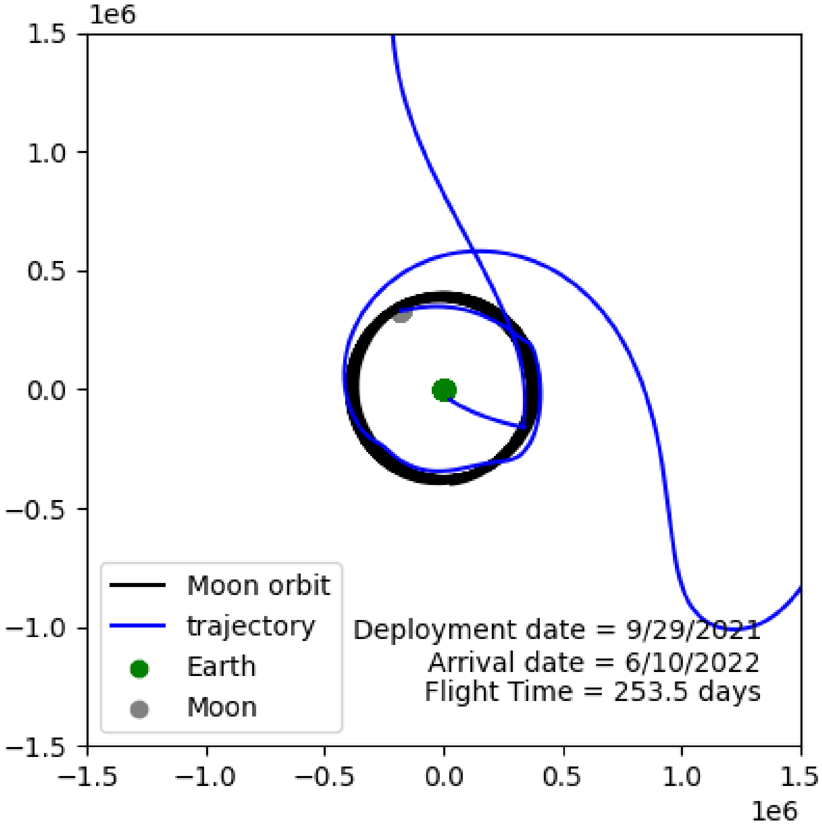


High-Fidelity

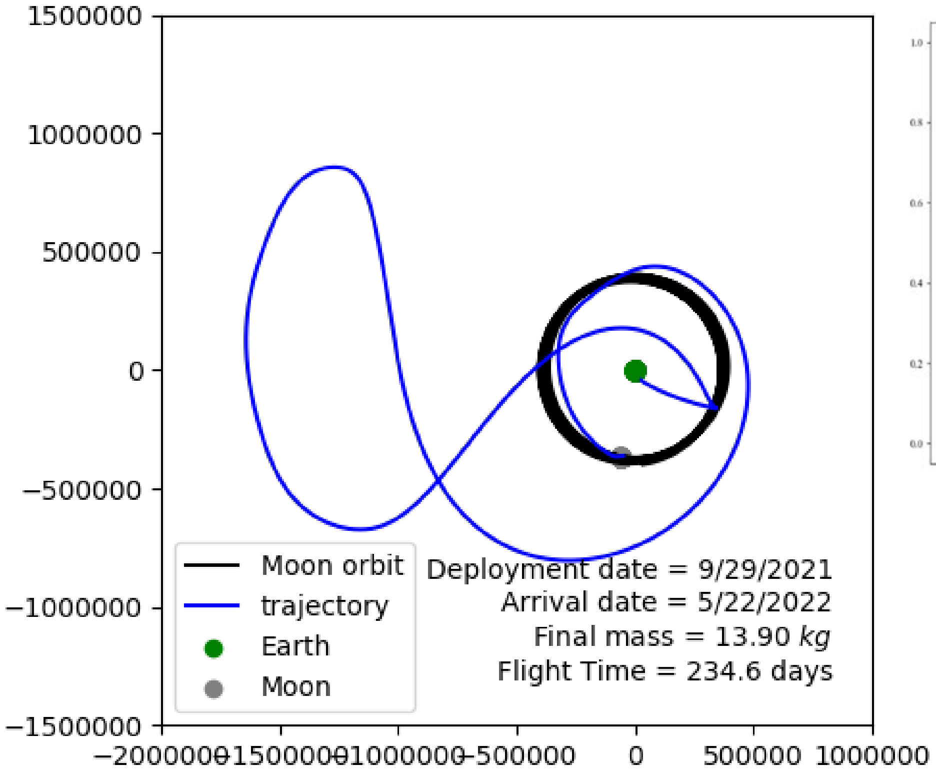
(GSE frame)

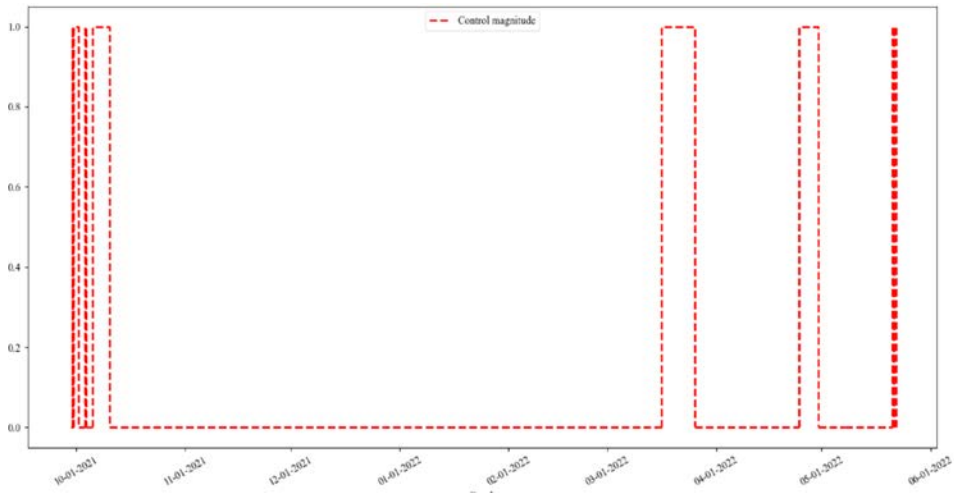
High-Fidelity Arrival Date Trade Study





May 22nd Arrival Case, High-Fidelity





Control Magnitude Profile

Conclusions

- Multi-point direct shooting and monotonic basin hopping are promising candidates for the design of Lunar IceCube and similar missions.
- This was an experiment – the techniques used here were developed for interplanetary missions and this is our first attempt at using them for a cislunar design.
- The methods presented here allow us to quickly and flexibly re-design Lunar IceCube in response to changes in mission requirements and deployment conditions.
- This capability will be very important during operations as we re-plan as we fly to take into account error from orbit determination and maneuver execution.

Thank You

EMTG is available open-source at

https://github.com/nasa/emtg/