Postdoc Research

Relative Phasing Transfers Leveraging Low-Thrust : The Deployment of the INCUS Constellation

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Background

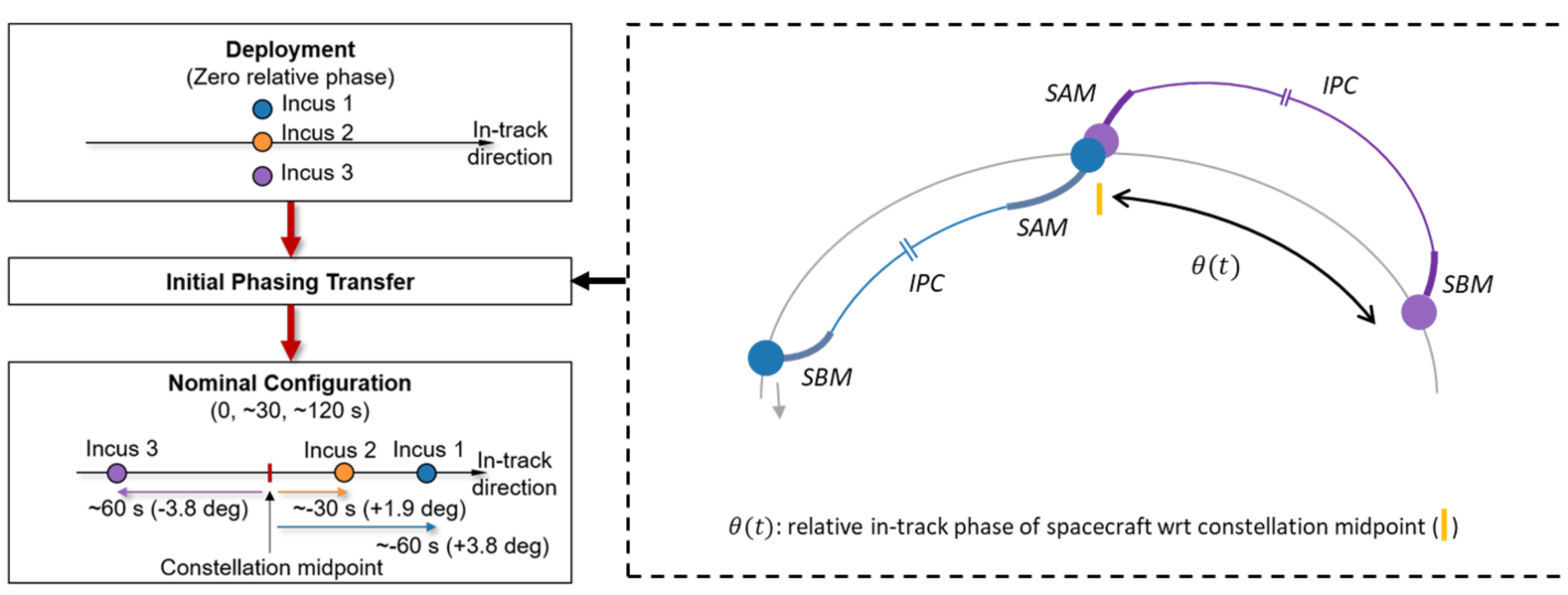
- **IN**vestigation of **C**onvective **U**pdraft**S** (**INCUS**) is a NASA Earth Venture Mission that will study the relationships between **convective mass flux in tropical storms** and **extreme weather**
- Launching in 2027, the constellation will be formed of **three low-thrust smallsats** located in a common orbital plane in **Low Earth Orbit** (LEO)
- The constellation will take ground observations with **defined time intervals**: 30 secs (+/- 10 secs) between observations from INCUS-1 and INCUS-2, and 120 secs (+/- 10 secs) between observations from INCUS-1 and INCUS-3

Objective

Development of a **framework for designing the deployment transfers of the INCUS constellation** after ejection from the Launch Vehicle (LV) using **low-thrust propulsion** and **considering various constraints and requirements** (LV dispersions, no-thrust periods due to eclipses or commissioning activities, …)

Approach

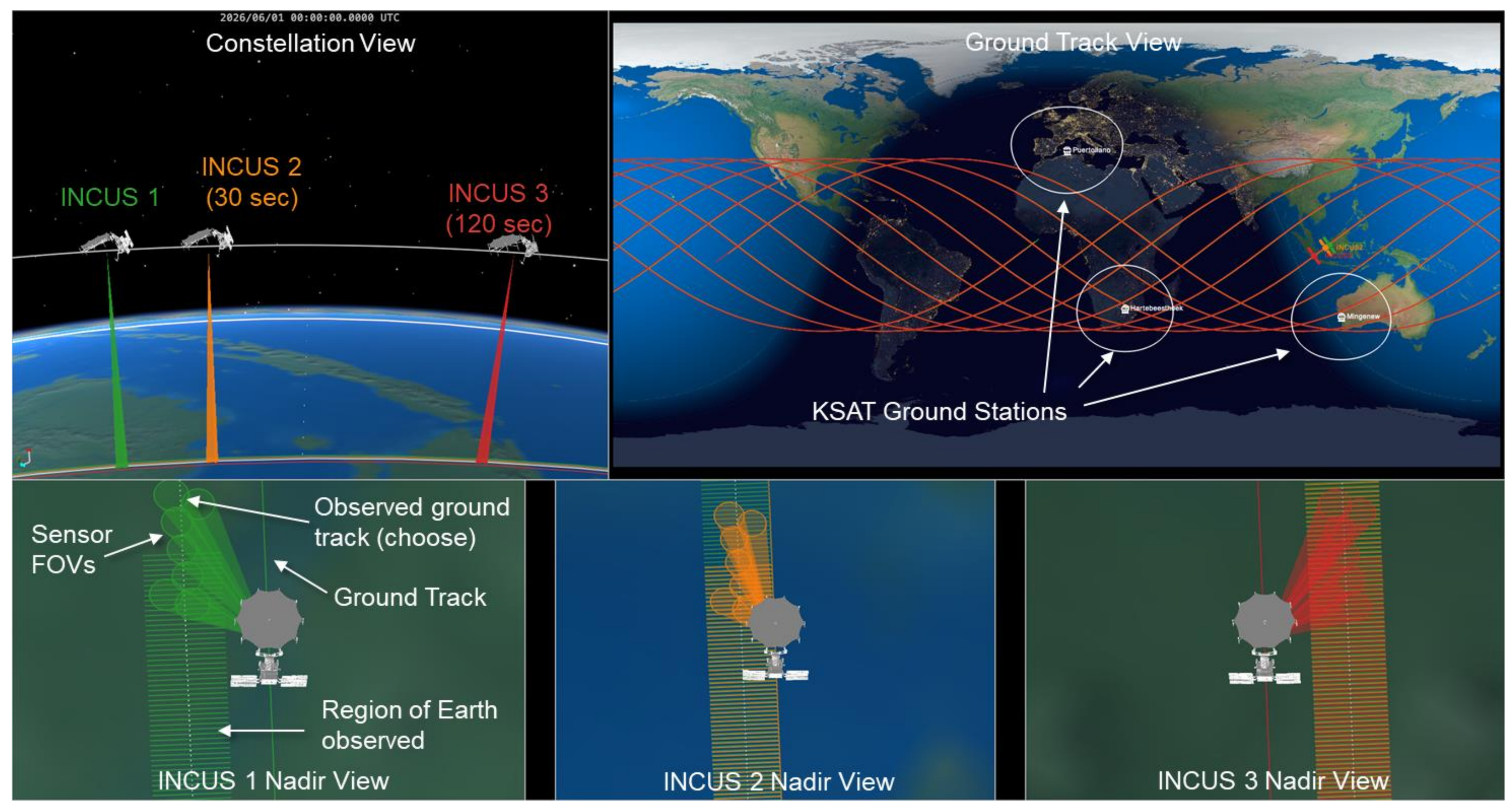
- Initial phasing transfer: combination of **Spiral Away Maneuvers** (**SAMs**), to set a relative drift rate between Observatories, and Spiral Back Maneuvers (**SBMs**), to cancel the drift rate at the end of transfer



- Developed **Double Spiral Transfer Algorithm** provides **closed-form solution** for **thrust directions** and **thrust durations** of low-thrust maneuvers :
  - Based on second-order differential equation modelling the relative in-track phase
  - Modeled: phase acceleration generated by low-thrust, phase rate from differential atmospheric drag between Observatories
- **Perturbations** and **constraints**, including differential drag, forced-coast periods, deployment velocity (with errors) are **included in algorithm**

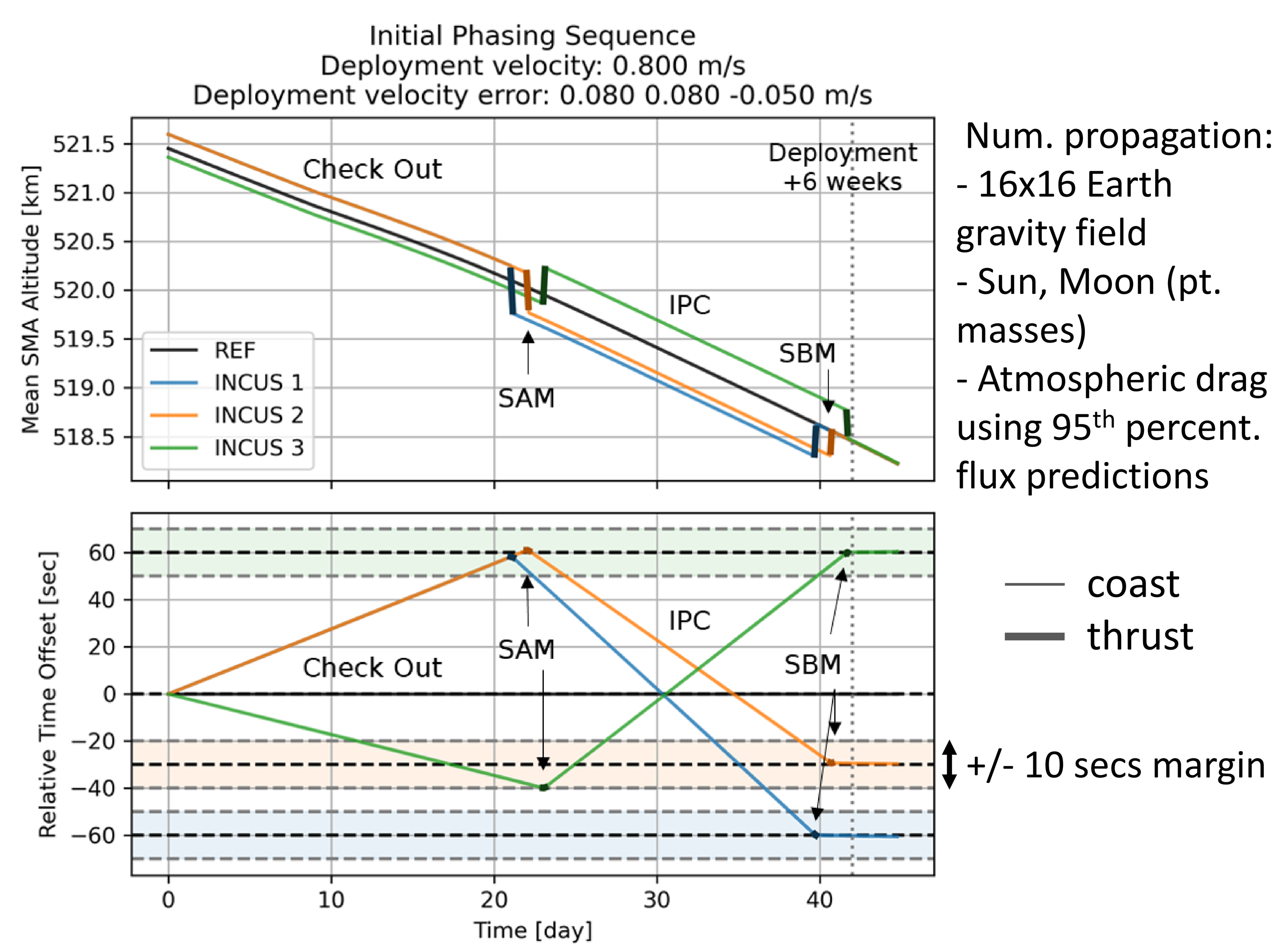
Significance of Results/Benefits to NASA/JPL

- Algorithm leveraging closed-form solutions allow rapid design and redesign of initialization sequence in early mission design analysis
- Deployment sequences successfully validated in higher-fidelity numerical simulations with a range of initial conditions and perturbations level



Results

- The developed algorithm was **extensively verified with numerical simulations** of the initial phasing sequence
- Notional deployment sequence below assumes worst-case scenario with ejection from LV along wrong direction



- Notional transfer characteristics (satisfy TOF < 6 weeks req.)

Observatory	INCUS-1	INCUS-2	INCUS-3
Thrust profile	-1, 1	-1, 1	1, -1
TOF (days)	39.8	40.7	41.7
Thrusting time (hours)	6.49	5.25	5.23
ΔV (m/s)	0.449	0.364	0.362
Propellant used (gr)	7.26	5.88	5.86

Future Work

Increase in fidelity in the representation of the deployment sequence, including addition of frozen orbit elements targeting

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