Ad Hoc CubeSat Constellations: Secondary Launch Coverage and Distribution

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Outline

- Motivation
- Approach
  - Launch opportunities
  - Case Studies
- Coverage analysis and observations
  - On-board propulsion
- Conclusions

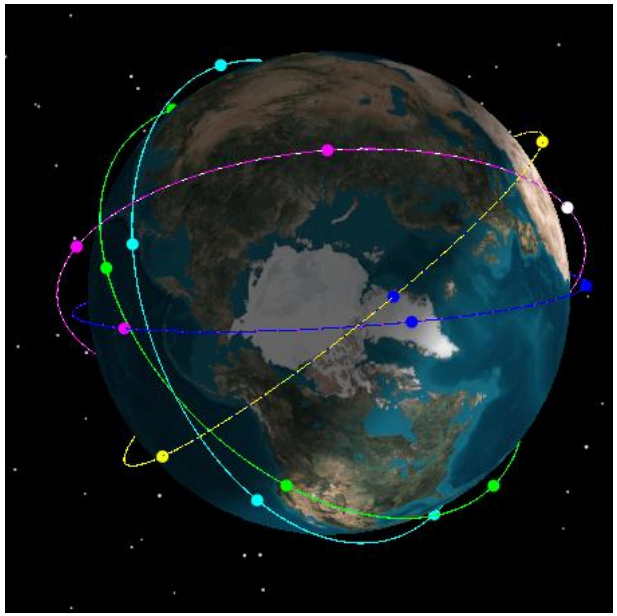
Motivation

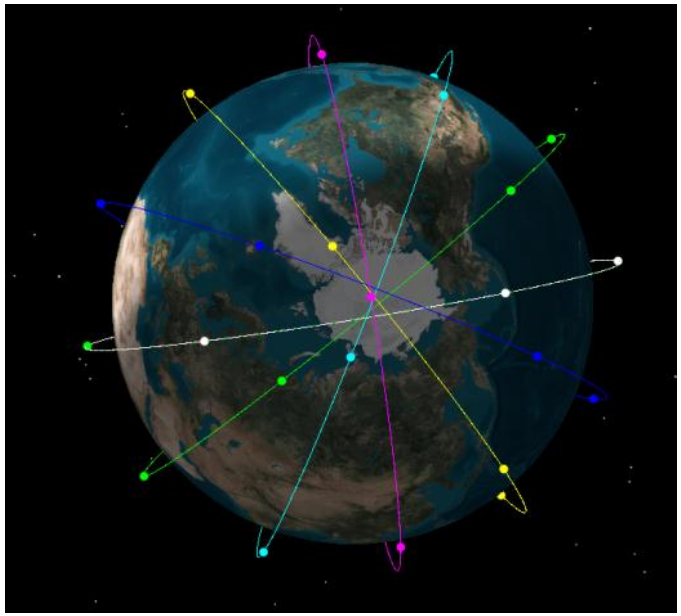
- CubeSat Constellations
  - Higher spatial and temporal resolution
  - Smaller, cheaper satellites

- Launch challenges
  - Secondary payload – cheaper, but variable
  - Primary payload – more expensive, but guaranteed orbits of choice

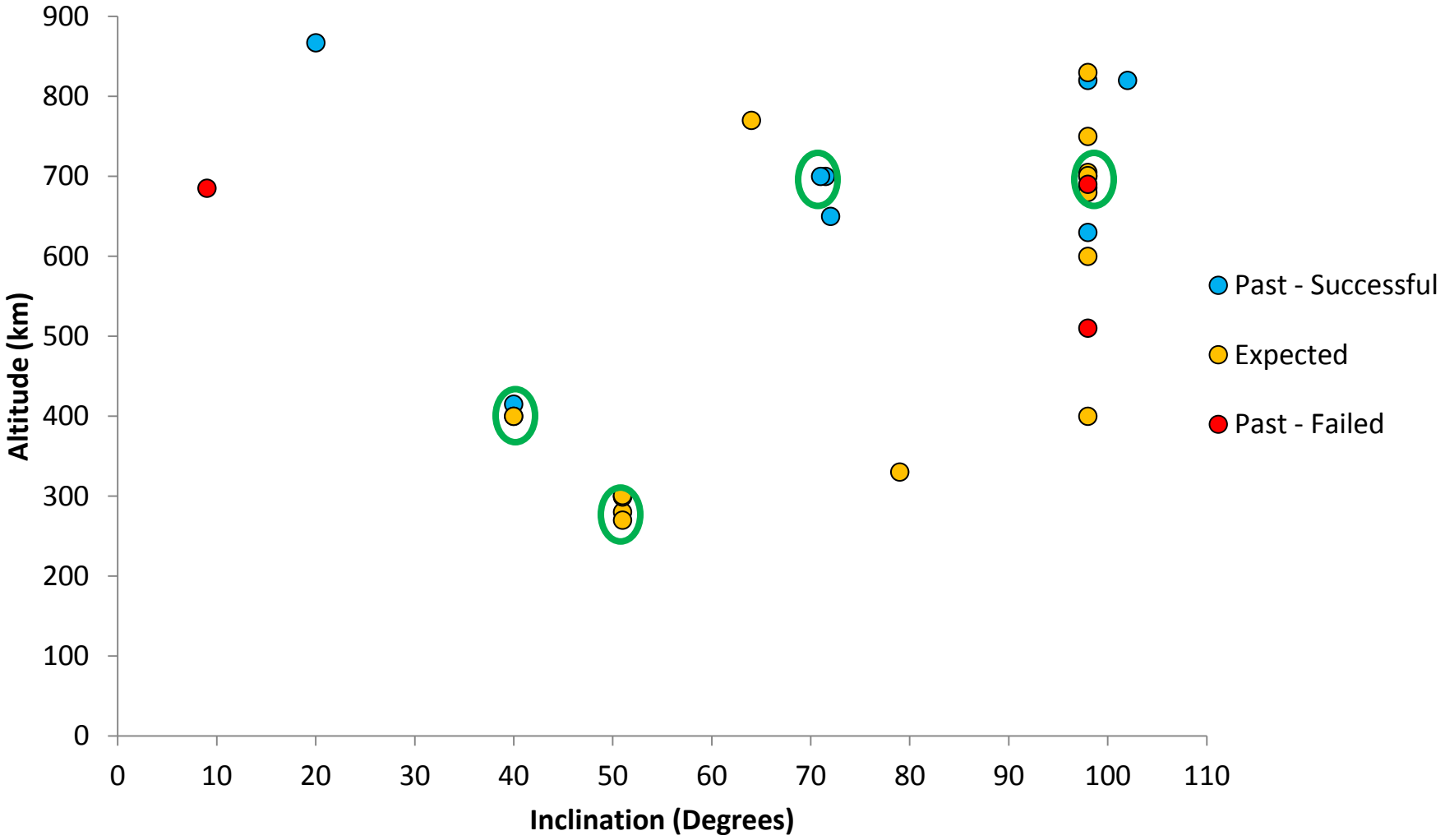
Questions

- Would an ad hoc constellation give comparable science to a planned configuration?
- What would be required to make it a reality?
  - Propulsion: distribution, overcoming drag
  - Launch opportunities





CubeSat Launches



http://space.skyrocket.de/doc_sat/cubesat.htm

Broad Agency Announcement: Edison Small Satellite Flight Demonstration Missions

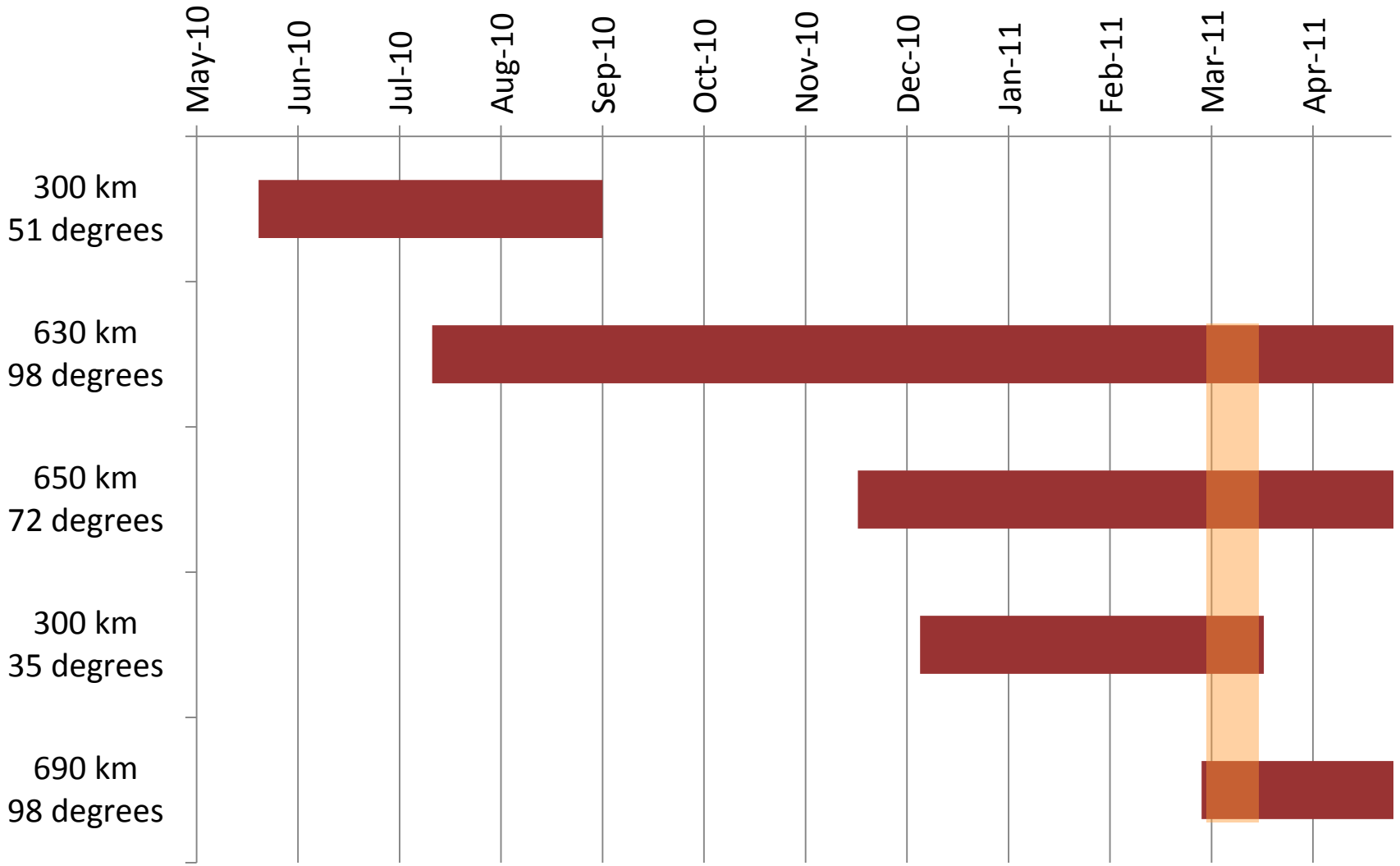
Case Studies

- Case 1
  - 2010-2011 CubeSat launch opportunities
- Case 2
  - 2012-2013 CubeSat launch opportunities
  - A: No on-board propulsion
  - B: On-board propulsion to distribute satellites and negate drag
- Case 3 (Reference)
  - 6 evenly distributed orbital planes,
  - 781 km, 86° (based on Iridium)

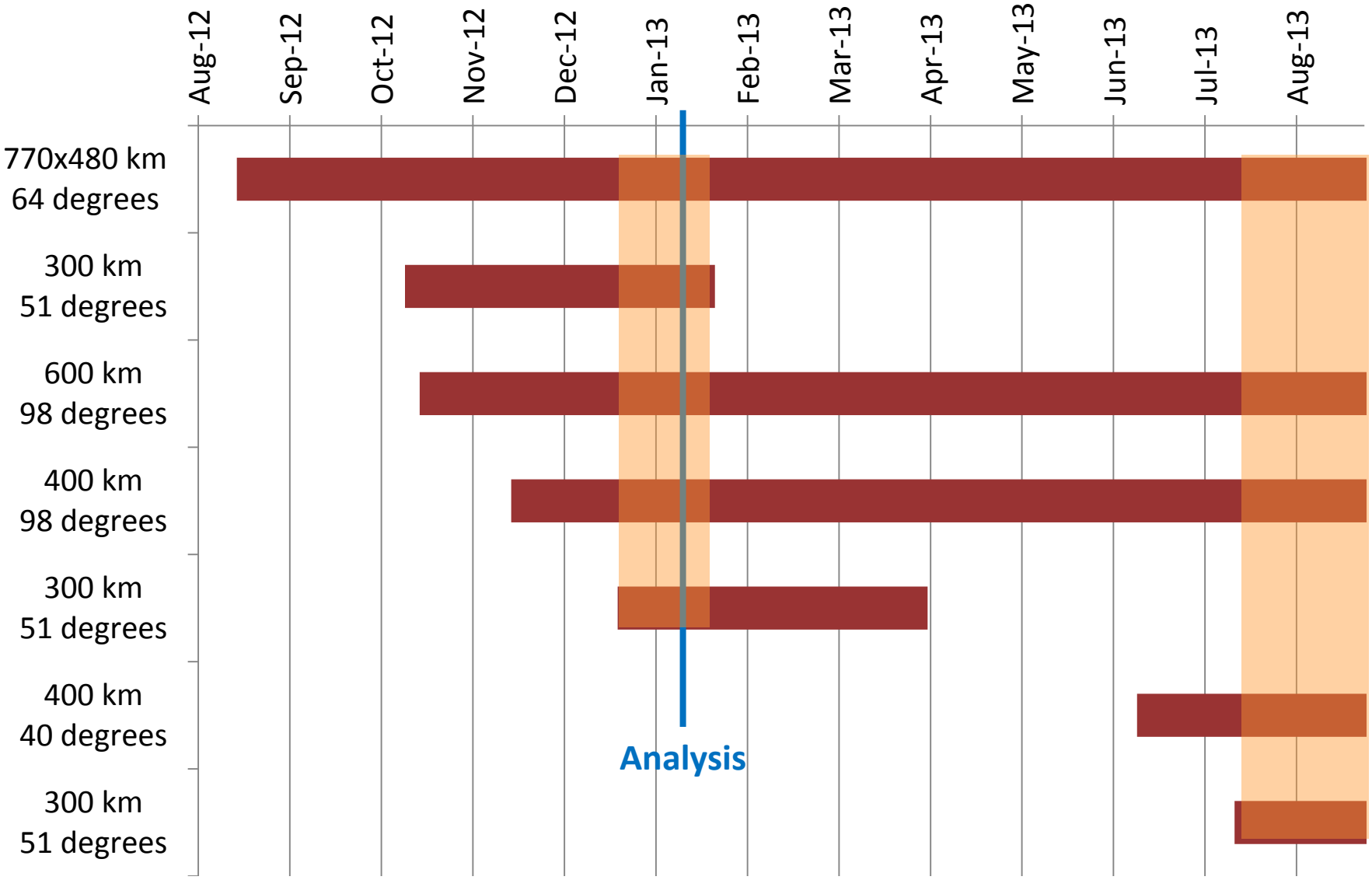
Case Studies

Case	Date	Altitude (km)	Inclination (°)	Launch Facility
1	5/20/2010	300	51	Tanegashima
	7/12/2010	630	98	Sriharikota
	11/19/2010	650	72	Kodiak
	12/8/2010	300	34.5	Canaveral
	3/4/2011	690	98	Vandenberg
2	7/12/2012	300	51	Tanegashima
	8/14/2012	770 x 480	64	Vandenberg
	10/2012	600	98	Dombarovsky/Yasniy
	10/2012	750	98	Sriharikota
	10/2012	275	51	Wallops
	12/21/2012	300	51	Canaveral
	2012	300	51	Tyuram/Baikonur
	2012	400	98	Kauai
	Summer 2013	400	40	Wallops

Case 1 Launch Profile



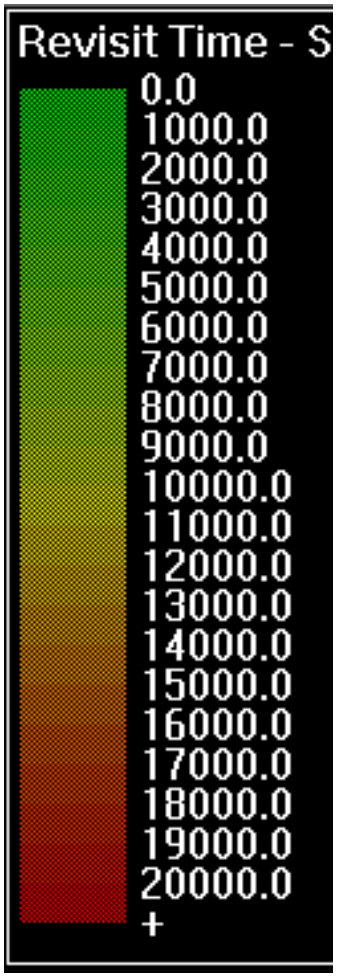
Case 2A Launch Profile



Coverage Analysis Assumptions

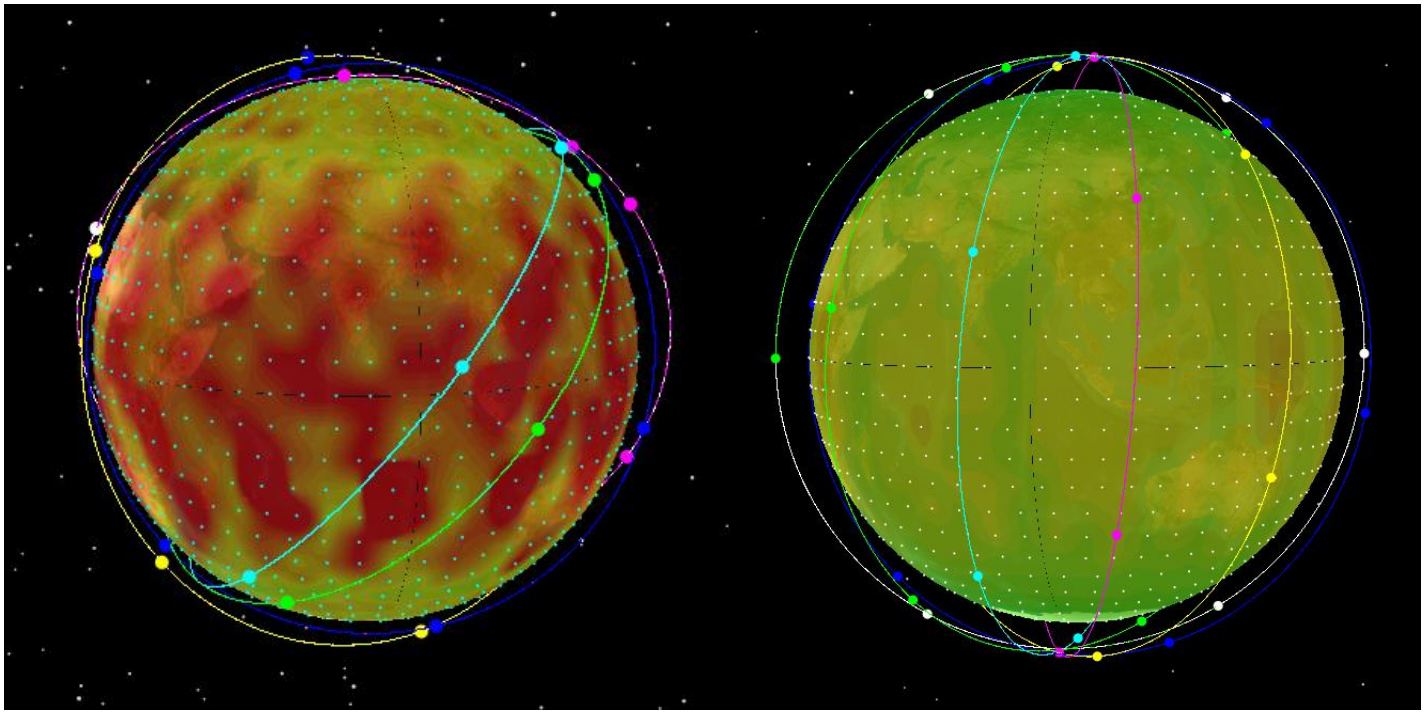
- Focus: revisit time
  - Average time between satellite coverage for each spot on the Earth
  - Analysis performed over 24-hour period
- Identical 3U, 4 kg CubeSats
  - 0.01 m^2 drag profile
- Sensor footprint – 45° cone
- One year (or time to deorbit) satellite lifetime

Coverage: 1 Satellite per Plane



Case 2 (Ad Hoc)

Reference Case



- Reference case shows more frequent coverage
- 3-5 hours max revisit time for either

Creating a Constellation

- Use on-board propulsion to distribute multiple satellites across orbital planes
  - Could also use to counter orbital decay due to atmospheric drag (extend mission lifetime)
- Disadvantages:
  - Adds mass and complexity to system
- Constellation size limited by:
  - Number of satellites on each launch vehicle
  - Initial orbital altitude (duration)

On-Board Propulsion

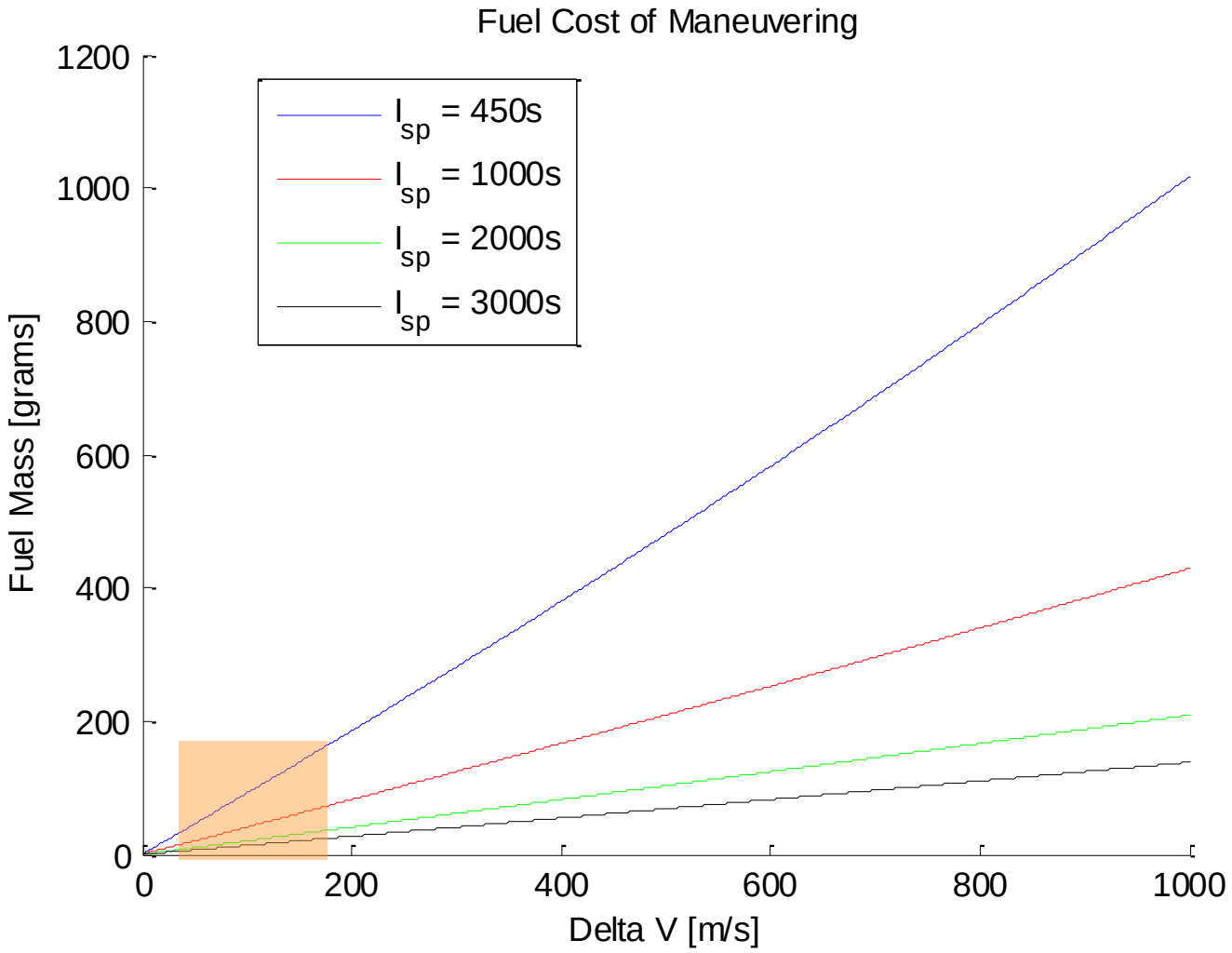
Altitude (km)	Inclination (°)	Maneuver Time [days]	Maneuver ΔV* [m/s]	Mission Life with no Drag Compensation** [days]	Extra ΔV for 1 Year Mission Life** [m/s]
300	51.0	31.4	22.5	49.5	145.3
400	40.0	32.1	12.6	402.0	N/A
705	98.2	34.3	10.6	> 405	N/A
650	72.0	33.9	10.7	> 405	N/A

* Assumes Isp of 1000 s

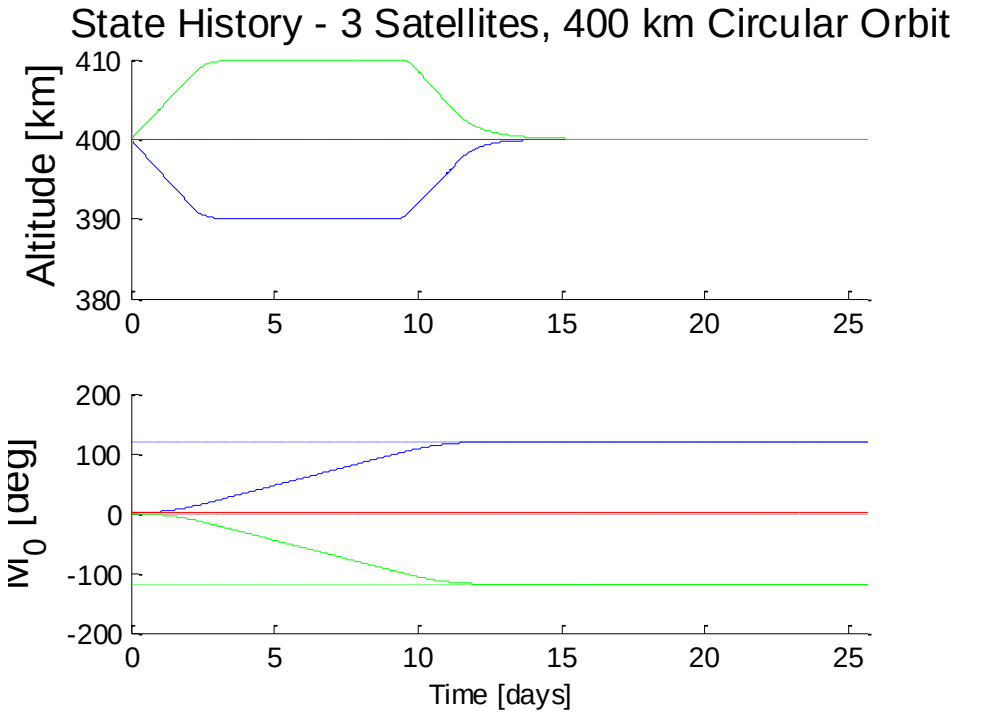
** After proper distribution has been achieved

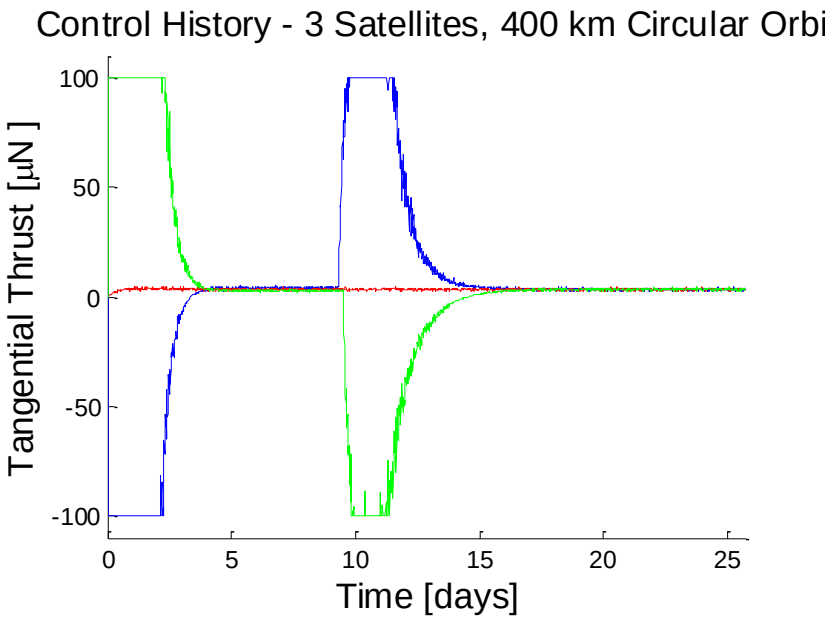
- About a month required to distribute 6 satellites over one orbital plane
- Baseline electrospray thrusters (Isp 1000 s)

Amount of Propellant Needed

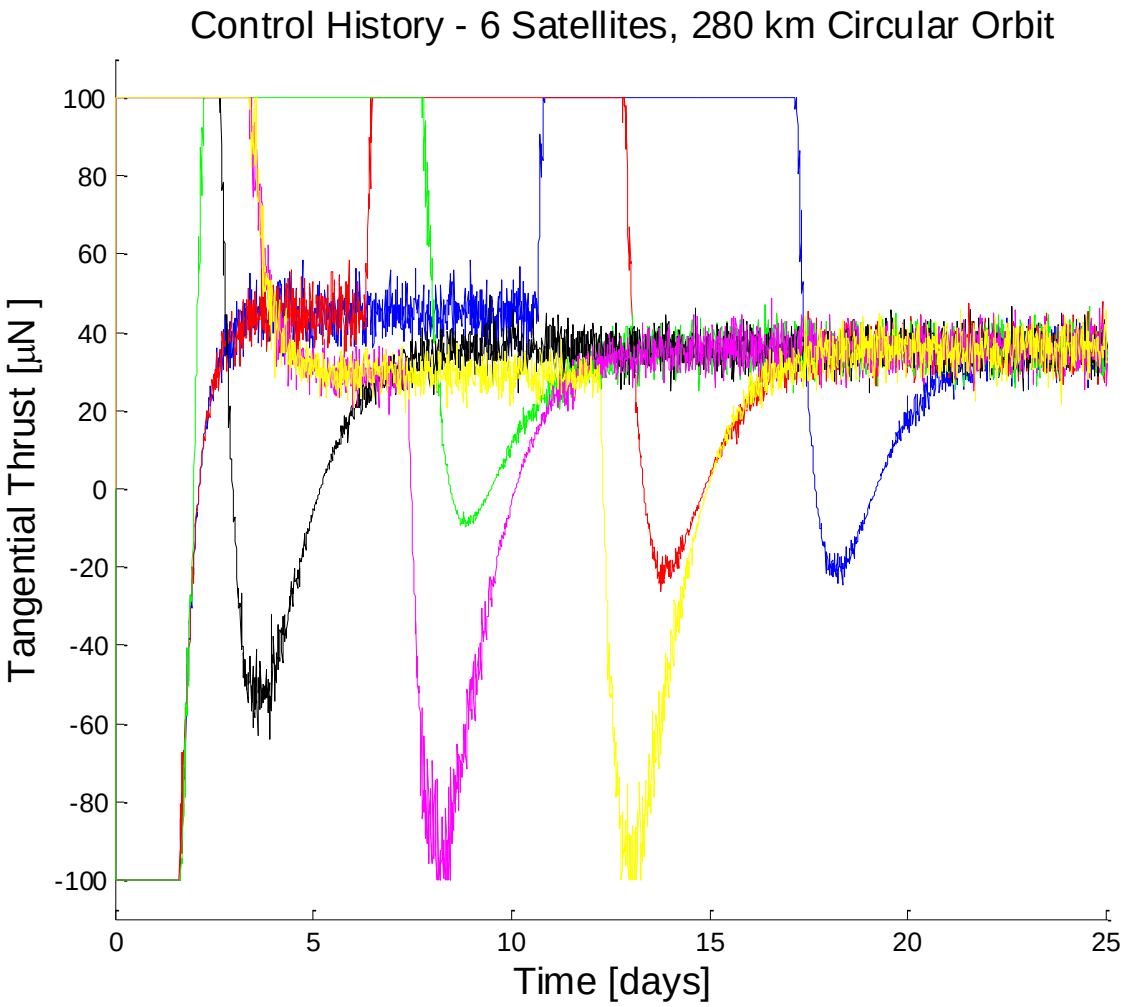


Orbital Positioning – 400 km

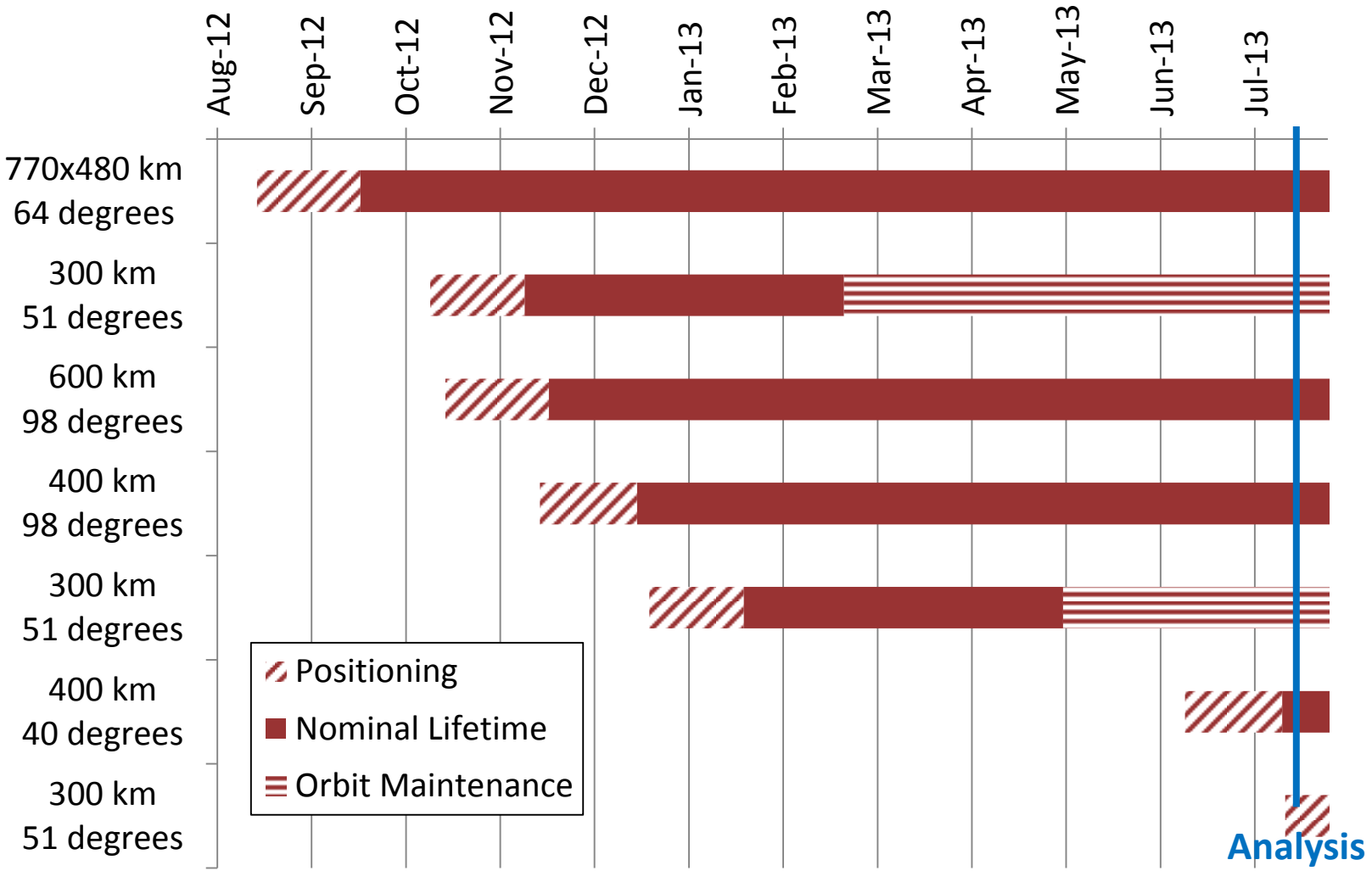




Orbital Positioning – 300 km



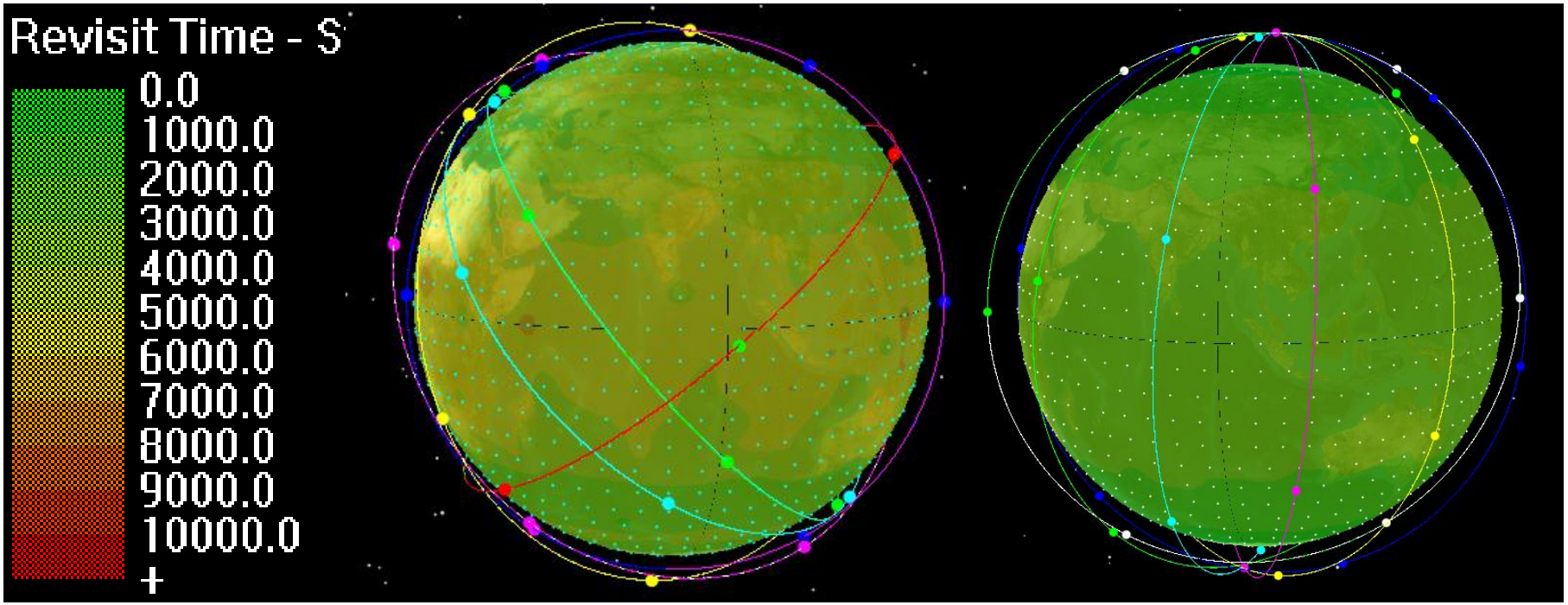
Case 2B Launch Profile (with propulsion)



Average Revisit Time: 3 Satellites per Plane

Case 2B

Reference Case

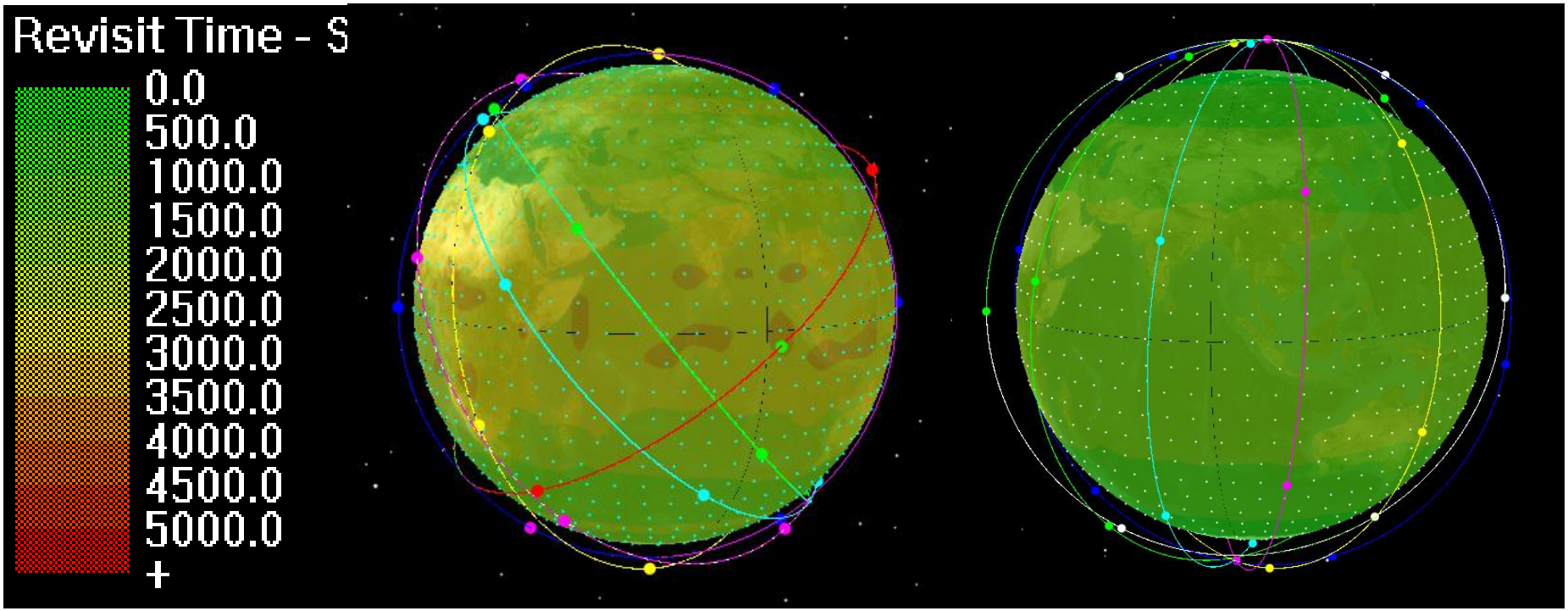


- Case 2 maximum around 1.4 hours
- Reference case maximum around 1 hour

Average Revisit Time: 6 Satellites per Plane

Case 2B

Reference Case



- Case 2 maximum around 1 hour
- Reference case maximum around 30 minutes

Future Considerations

- Goal – achieve revisit time comparable to reference constellation
- Higher altitudes generally better
  - Less deltaV to maneuver and distribute
  - Less fuel required to counter drag
  - Larger swath for given sensor FOV
  - But, fewer launch opportunities
- Sensitivity analysis:
  - Launch schedule
  - Available orbits
  - Sensor FOV
- Extend analysis to include all possible LEO launch options

Summary

- Secondary launch opportunities are a cost-effective option for CubeSat constellations
- Without propulsion, worst-case revisit time is 5 hours
- With propulsion, worst-case revisit time is 1 hour
- On-board propulsion enables more satellites per plane (better science coverage)
  - One month to distribute properly
  - Combat atmospheric drag to extend mission life