SkySat Block 3 Launch Campaign

Monte Fitz Roy, Patagonia – March 19, 2018

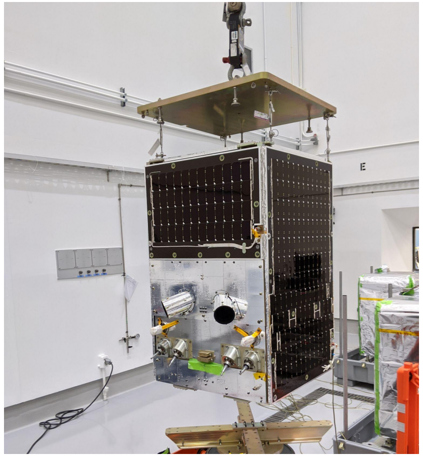
Our Speakers

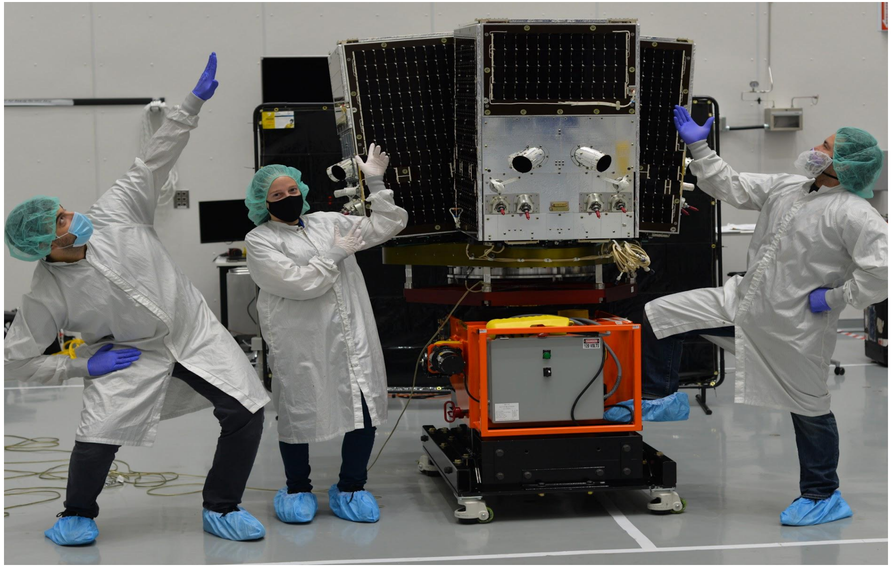
Lisa McGill
SkySat Mission Ops

Addison Faler
Guidance, Navigation and Control

PLANET'S MISSION

To image the whole world every day, making change **visible, accessible, and actionable**.





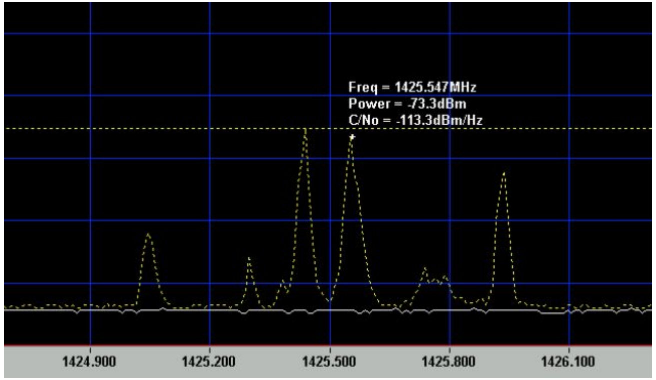

IRCO

Ground Station Network

- Awarua, New Zealand
- Goonhilly, United Kingdom
- Maddock, North Dakota, USA
- Punta Arenas, Chile
- Jeju Island, South Korea

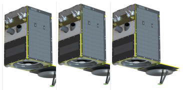
Launch Day

- 10 minutes to space
- 12 minutes to launch vehicle separation
- 18 minutes to first ground station contact



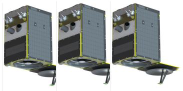
Falcon 9 (Cape Canaveral, FL)

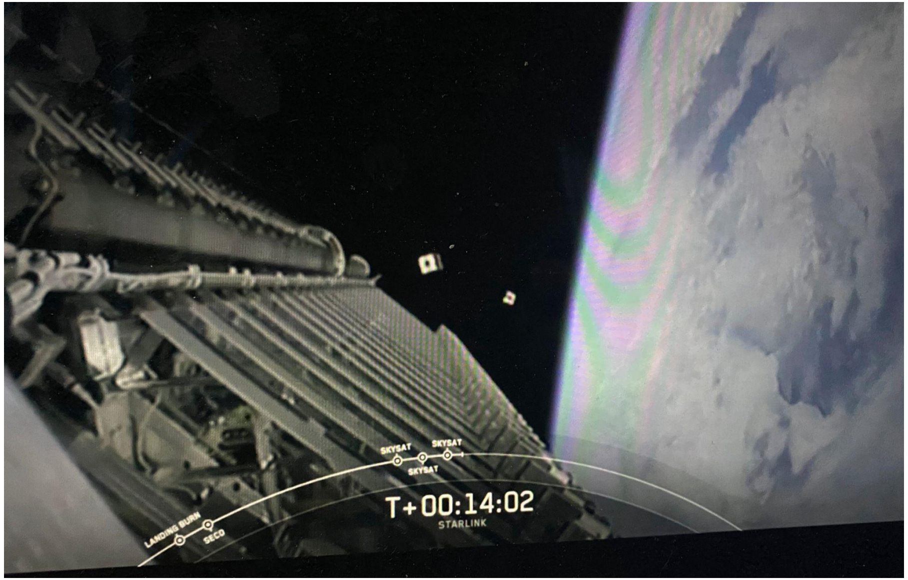
Launch: 6/13/2020



Falcon 9 (Cape Canaveral, FL)

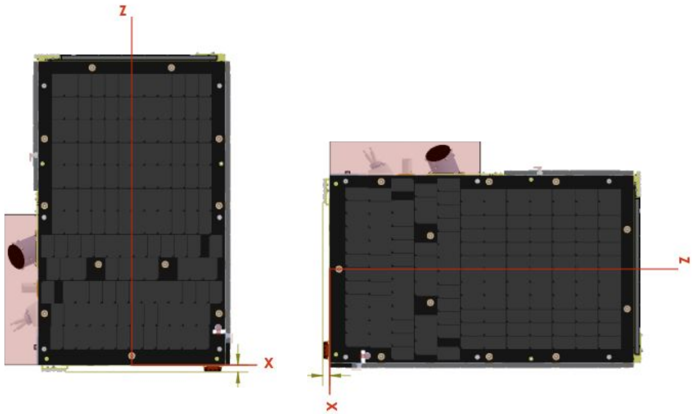
Launch: 8/18/2020



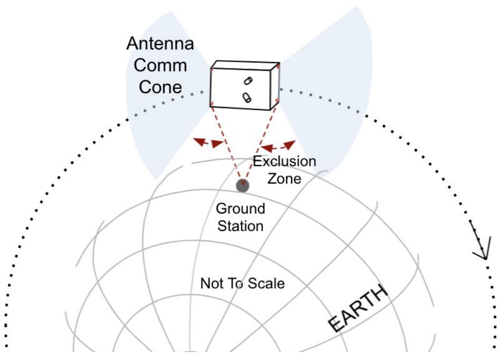


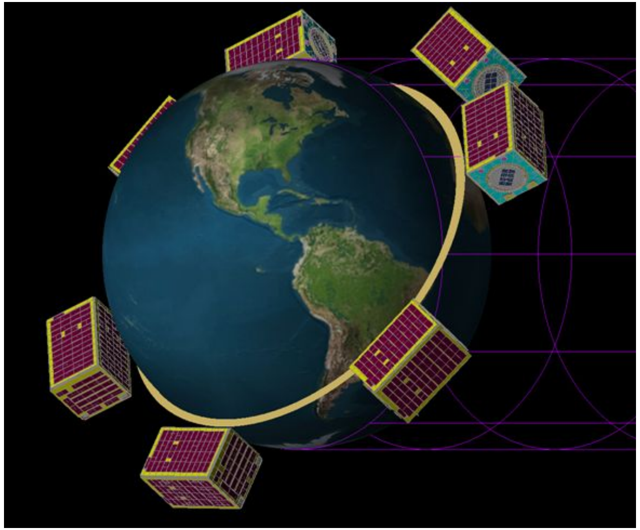
Low Drag

- Pitch 90 degrees to expose its smallest cross-section to be parallel to velocity direction
- Payload door remained closed
- Reduce atmospheric drag
- Updates to ops scripts to support telemetry and commanding



High Drag Low Drag



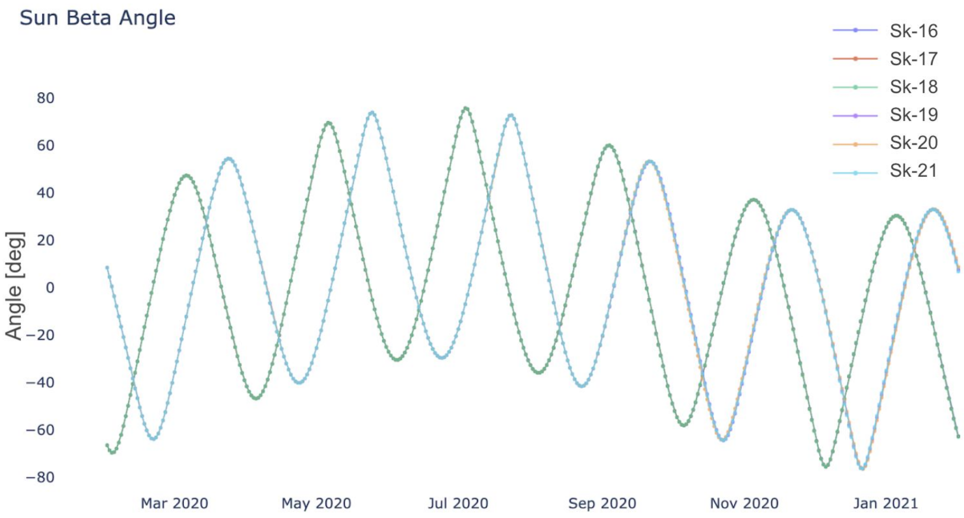


Attitude Management

What is a beta angle?

- A measurement that describes the angle between a satellite's orbital plane and a vector from the center of the Earth pointing toward the sun

Develop a new attitude management scheduling system!



Beta Angle Magnitude	Classification	Issues
$0 \leq \beta \leq 15$ deg	Low Beta	Poor star tracker performance
$15 < \beta < 45$ deg	Mid Beta	No issues
$45 \leq \beta < 68$ deg	High Beta	High temps; thermal buildup
$\beta \geq 68$+ deg	Extreme Beta	No eclipses; severe thermal buildup

On-Orbit Operations

Singapore Strait, Singapore – July 29, 2016

On Orbit Issues

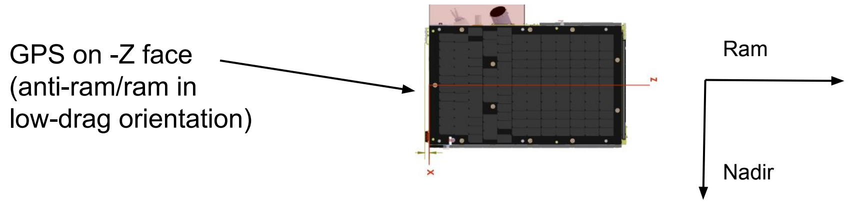
Two Primary Issues

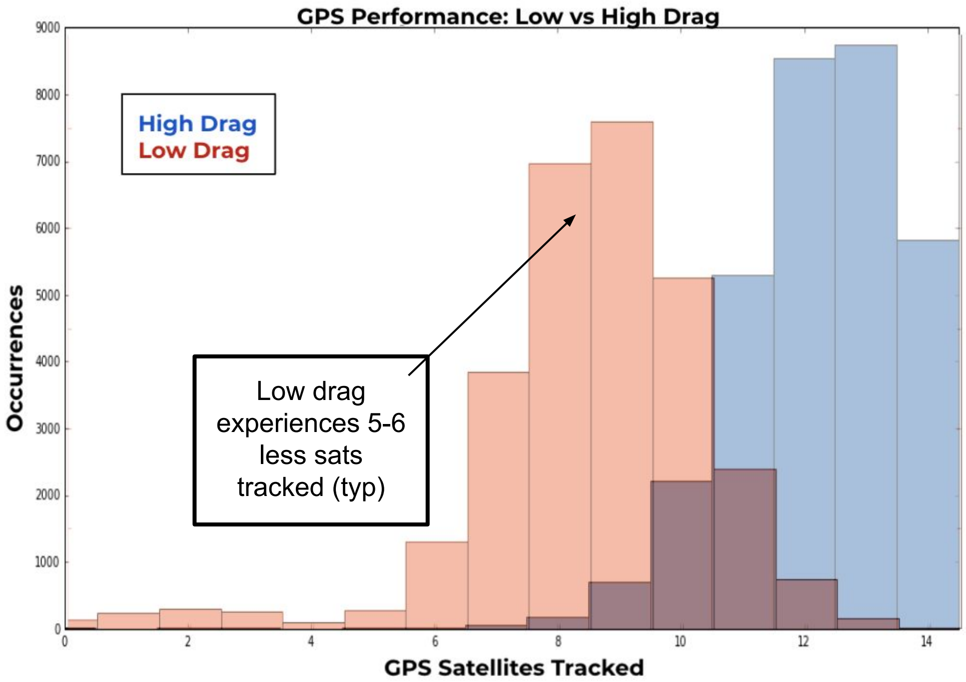
Unexpected GPS Loss:

- During commissioning (in low-drag) experienced higher occurrence of GPS lock/solution dropouts
- Sustained dropouts can cause ACS faults, due to degradation in position knowledge
- Compared performance to high drag SkySats - it was confirmed this was product of GPS antenna orientation whilst in low-drag, towards horizon (ram/anti-ram) vs anti-nadir
- Mitigation: When needed, used GPS override mode (uses onboard propagator and TLE to approximate position temporarily)

Non-Operational Thruster:

- Sensor anomaly monitoring thruster on SkySat-20
- Out of precaution deemed thruster non-operational
- Shifted to “reduced thruster operations” i.e 3-thruster Ops
- Following slides detail...





TLE - two line element

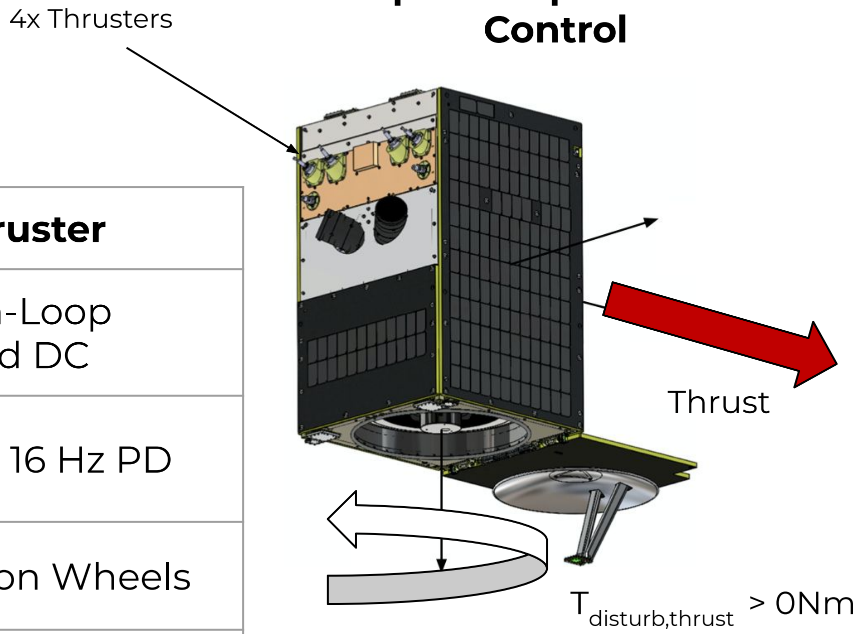
Maneuver ADCS

Nominal vs 3-Thruster

	Nominal	3-Thruster
Thruster Control	Closed-Loop PID 1Hz - Variable DC Optimization[2]	Open-Loop Fixed DC
Attitude Control		Nominal 16 Hz PD
Actuators	4x Thrusters	4x Reaction Wheels
Sensors[1]	Gyros	Gyros
Duration	~300-360sec	70-100sec

[1]Star Trackers occluded by Plume
[2]Convex Optimization -- to max DC and satisfy nullspace (Thrust won't impart torque on vehicle)
PID: Proportional–Integral–Derivative

Open Loop Thruster Control



Maintain pointing ?
Nominal ACS controller using RWs (to counter $T_{disturb,thrust}$)

How to calculate open loop DC's ?

Reduced Thruster Maneuvers

Selecting Duty Cycles

Objective: Maximize Impulse

$Imp = F_{th} * t_{dur}$ = Thrust * duration [N-s]

Variables:

Duty cycles of 3-functioning thrusters[1]

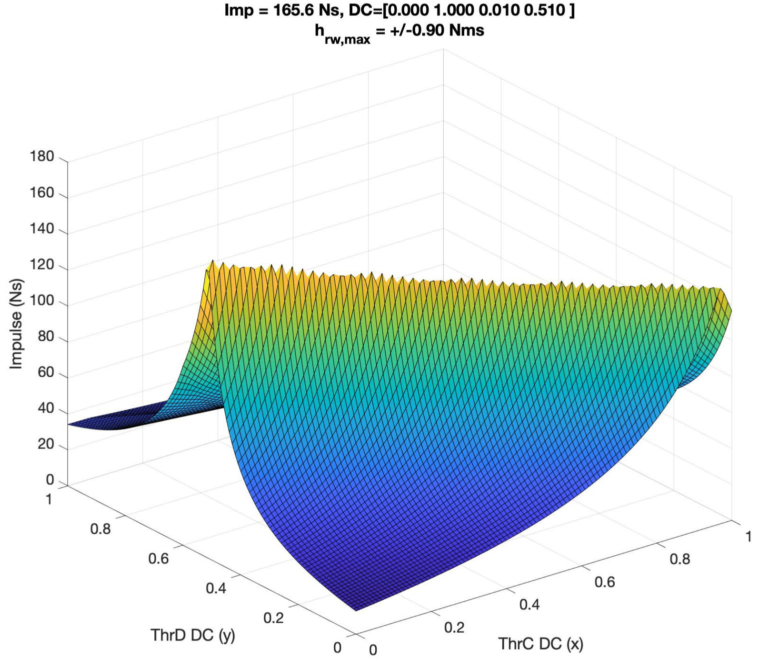
Where:

F_{th}, Thrust = f(DC)

T_{dist}, Disturbance Torque = f(DC)

t_{dur}, Burn Duration = $h_{rw,max} / T_{dist}$

$h_{rw,max}$, Total Available RW Momentum



Example of Thruster duty cycle optimization: Holding one thruster fixed (B) and solving for Thruster C & D duty cycles

[1]technically 2-thrusters, we hold one constant to zero for simplicity

Nominal 3-thruster Maneuver

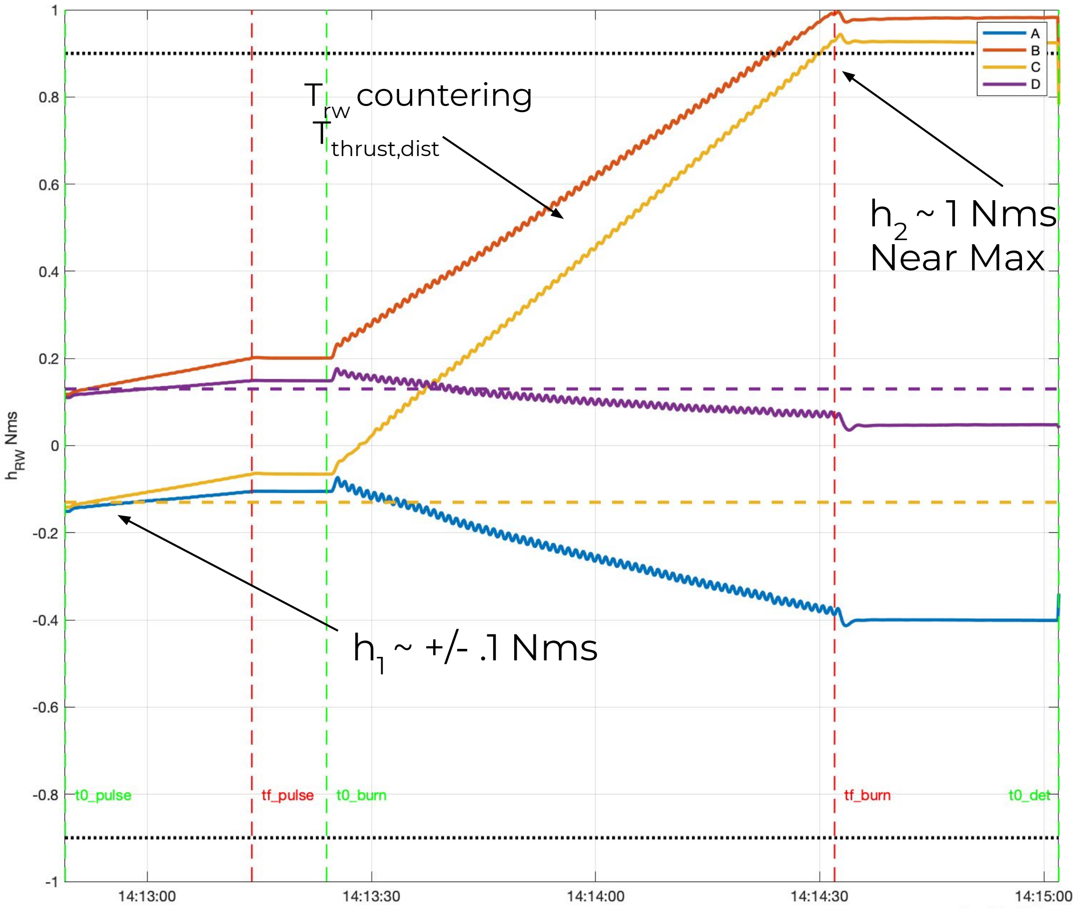
RW Momenta

No-RW Prebias
Burn Time: 70 seconds
Total Activity Time: 1hr 20 min

Pros:
Activity/planning complexity is comparable to nominal 4-thruster maneuver

Cons:
Duration is minimal

Reaction Wheel Momenta



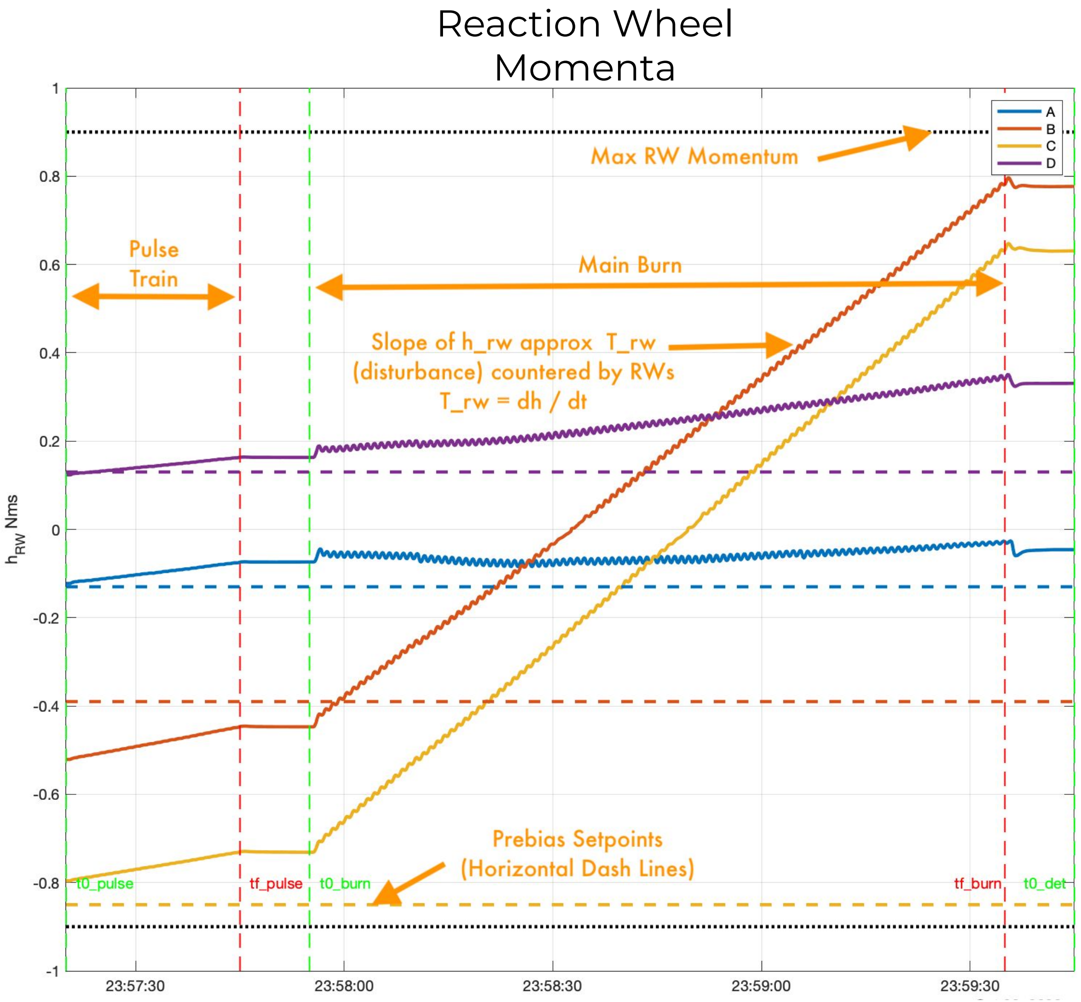
Nominal Pre-bias Maneuver

RW Momenta

RW Prebias
Burn Time: 100 seconds
Total Activity Time: 2hr 20 min

Pros:
Duration improved vs non-prebiased
~50% improvement in impulse

Cons:
Longer activity +1hr
Much more complex, planning and execution

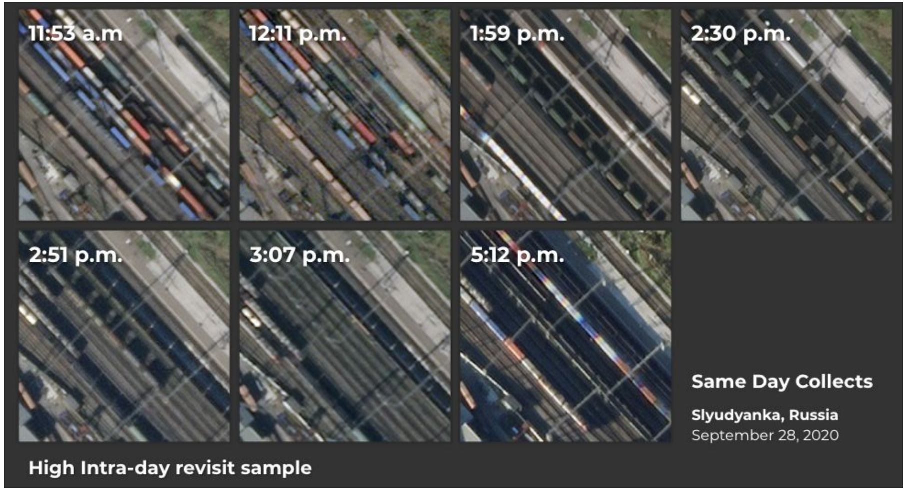


Orbits Strategy

Singapore Strait, Singapore – July 29, 2016

Constellation Goals

- 50 cm Resolution
- 6+ year lifetime
- phased to provide repeat-revisit
- **Repeat-Revisit:** multiple revisits over any single area are possible, with up to 12 times per day, and at a global average of 7 times per day



Orbit Raising Campaign

Initial orbit: 375 x 208 km ellipse

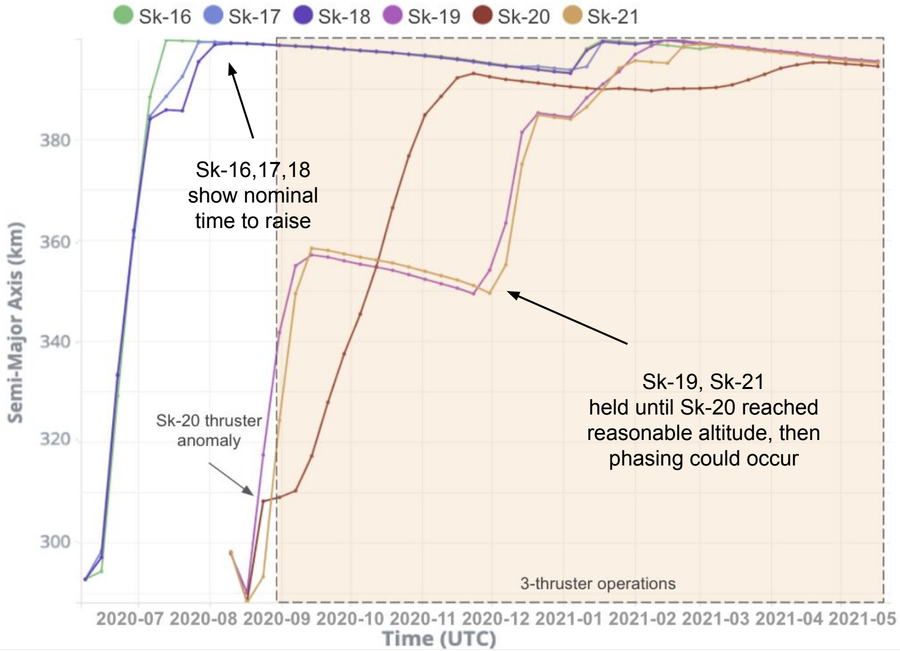
Target orbit: 400 km circular

Goal: raise perigee immediately, then phase appropriately

Impacts of 3-thruster Ops:

- Shorter maneuvers: 70-100 secs
    - vs 360 sec nominally (3.6-5x reduction)
- More maneuvers (3x days vs 1 per 2 days)
- Less ΔV, longer time to raise

Skysat-20 3-thruster operations delayed raising campaign for Skysat 19,20,21



Thank you!

Connect with us on LinkedIn

Lisa McGill **Addison Faler**

Woody Island, South China Sea – March 28, 2018