# CloudSat Status

13 June 2017

Mona Witkowski – CloudSat Flight Director
Barbara Braun – CloudSat Orbit Analyst

Jet Propulsion Laboratory, California Institute of Technology

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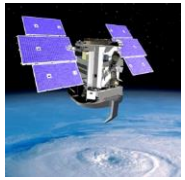
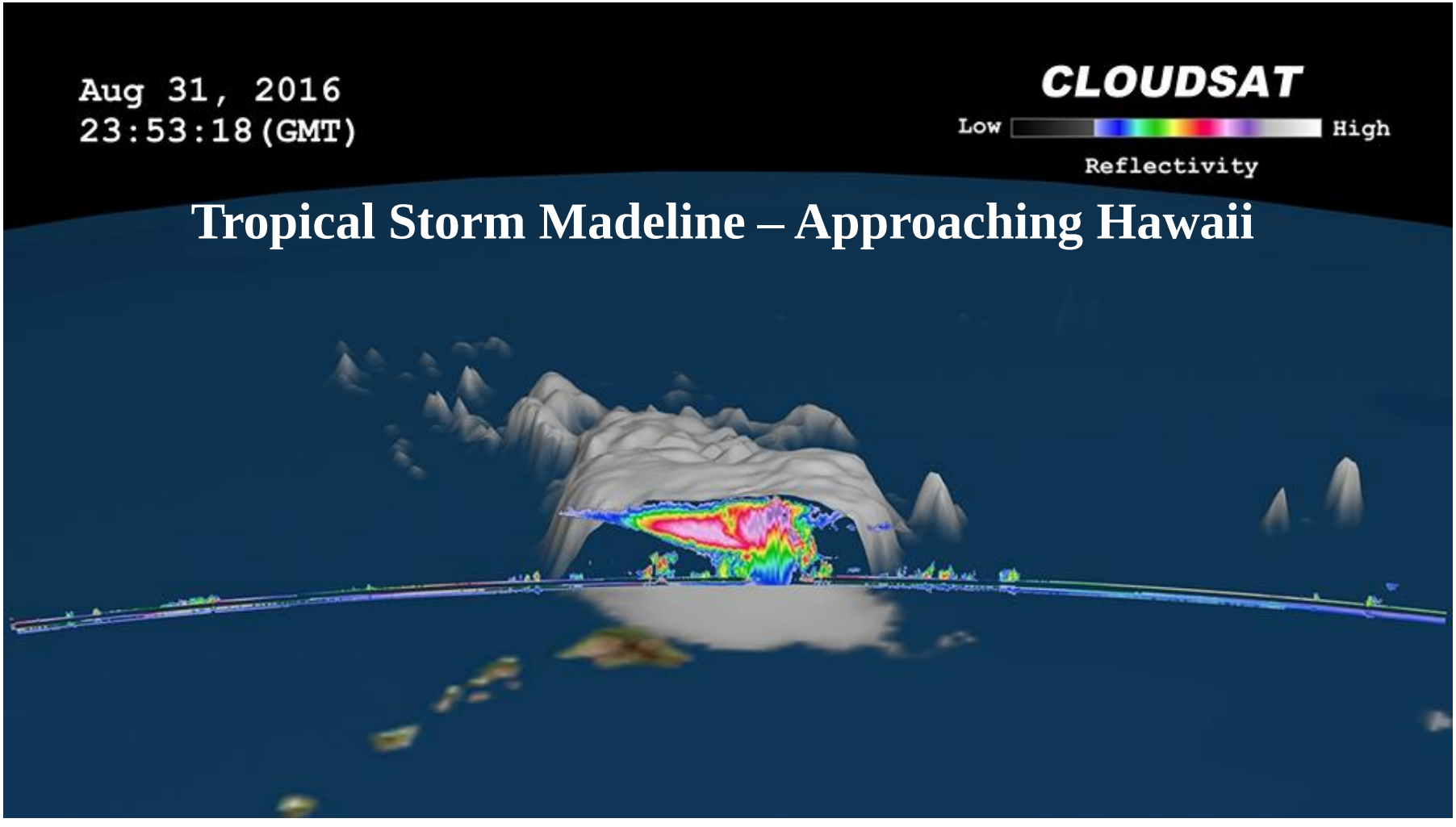
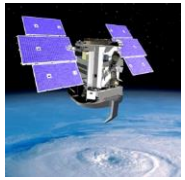
Government sponsorship acknowledged.

# Recent Overpass





# Mission Status



## *CloudSat celebrated 11 years in Orbit on 28 April!*

## Daylight Only Operations

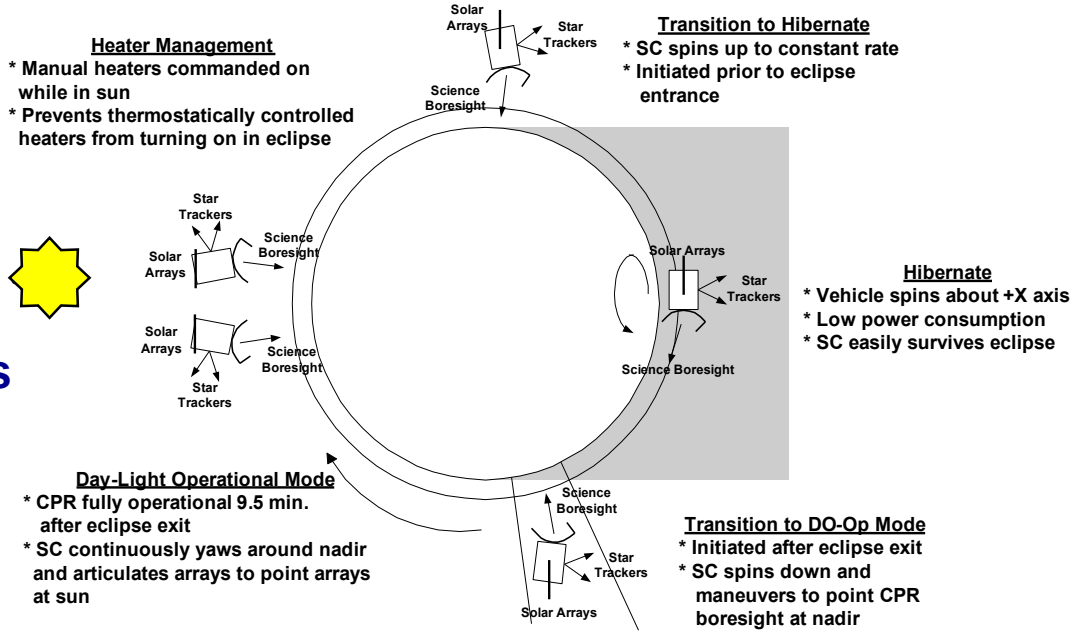
- Due to power restrictions
- Maneuvers in daylight also

## S/C Health is Excellent

- Life expectancy beyond FY '19

## S/C Health/Redundancy Status

- CPR is fully redundant
- April 2011 Battery Anomaly
  - June 2011 Left A-Train
  - Daylight Only Operations
  - May 2012 Rejoined A-Train
- May 2011 Receiver 1 Probable Loss
  - Locked up at an off-nominal frequency
  - May be recoverable
  - Recovery efforts to date have been unsuccessful

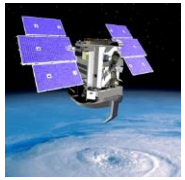



## Proactive Battery Management

- Battery Health Checks
- Manual Mode /KI Charging (MMKI)
- Steady State / Ki Charging (SASSI)
  - SASSI discontinued June 2017

# Accomplishments

*(Since the last MOWG)*



## Senior Review Proposal for FY ’18-’21

- Headquarters Briefing / Response to Questions: 10 May 2017

## Contingency On Orbit Handbook Revision

- Rev H released in December 2016
- Walk Through & Contingency Training @ RSC in January 2017

## Command Block Modifications

- T21 Blk 11 Updates for SASSI Testing: Nov ‘16 – Jan ‘17
- T21 Blk 4d2 (DO-Op2) Updates for SASSI & MMKI: Feb ‘17 – present
- T21 Blks 4 & 6 (DO-OP & PREP) - CPR On & CPR Main Htr On: 19 Apr ’17

## Star Catalog Rotations (2)

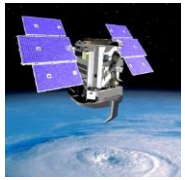
- December 2016
- June 2017

## Solar Eclipses (1)

- 26 February 2017
  - Commanded to STBY/PREP*4
  - 9 Orbits of CPR Science Data Lost

# Accomplishments

*(Since the last MOWG)*



**Battery Manual / KI (MMKI) Charge Mode Implementation**

- MMKI with KI Boost Characterization: Mar ’17 - *present*

**Steady State / KI (SASSI) Charge Mode Implementation**

- Characterized SASSI Implementation (w/VT 5.0): Jul ’16 – Feb ‘17
- SASSI with KI Boost Characterization: Feb ’17 – *present*
- SASSI Implementation Discontinued: Jun ‘17

**Spare Common Pressure Vessel (CPV) Operations**

- Recharge Operations Discontinued

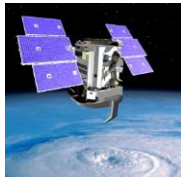
**Weekly Battery Health Checks Continue**

- Suspended from 30 May – 1 Aug ‘16 (due to seasonal loads)
- One orbit characterization per week (vs 3): 22 Aug ‘16 – *present*

**Magenetometer Model Update** (T53, 54 & 55)

- Development & Validation: Jan – Mar ‘17
- Implementation: 25 Apr ‘17

# Formation Flying



## Fly within the Constellation Control Box

- No excursion since the last MOWG in September 2016

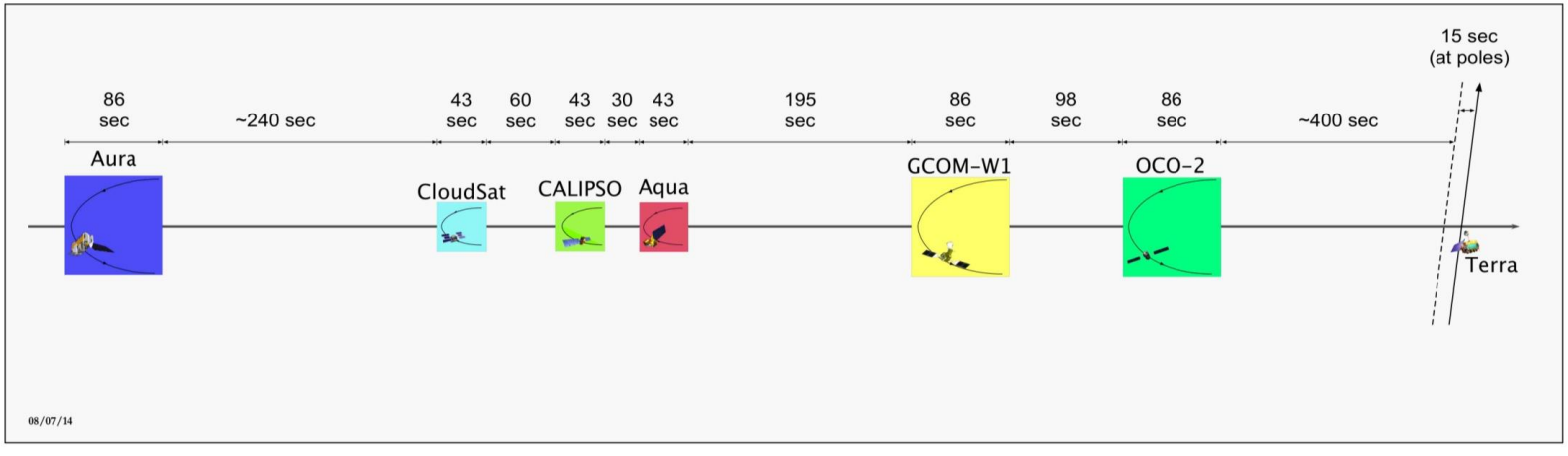
## Formation Flying Strategy

- Aim for 4km ground track overlap with CALIPSO 90% of the time
- Use Orbit Raises and Orbit Lowers as necessary
- No excursion since the last MOWG in September 2016

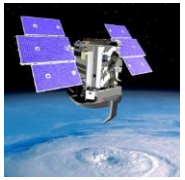
## 7 Maneuvers required since the last MOWG

- 2 Orbit Raises / 3 Orbit Lowers
- 2 Inclination Decrease Maneuvers (2017 IAM Campaign)

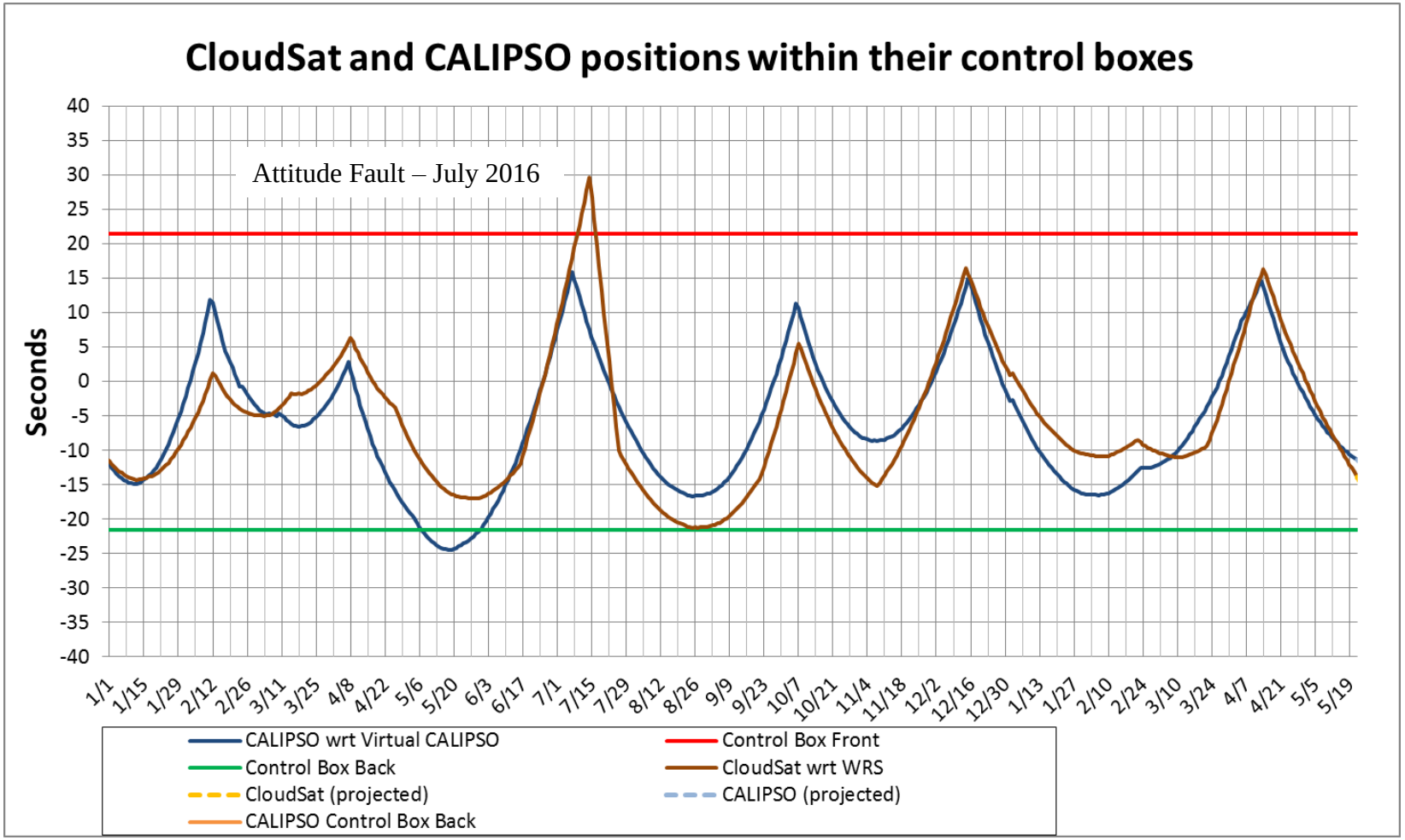
## No dedicated maneuvers required for COLA / Risk Mitigation



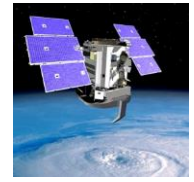
# Recent Performance



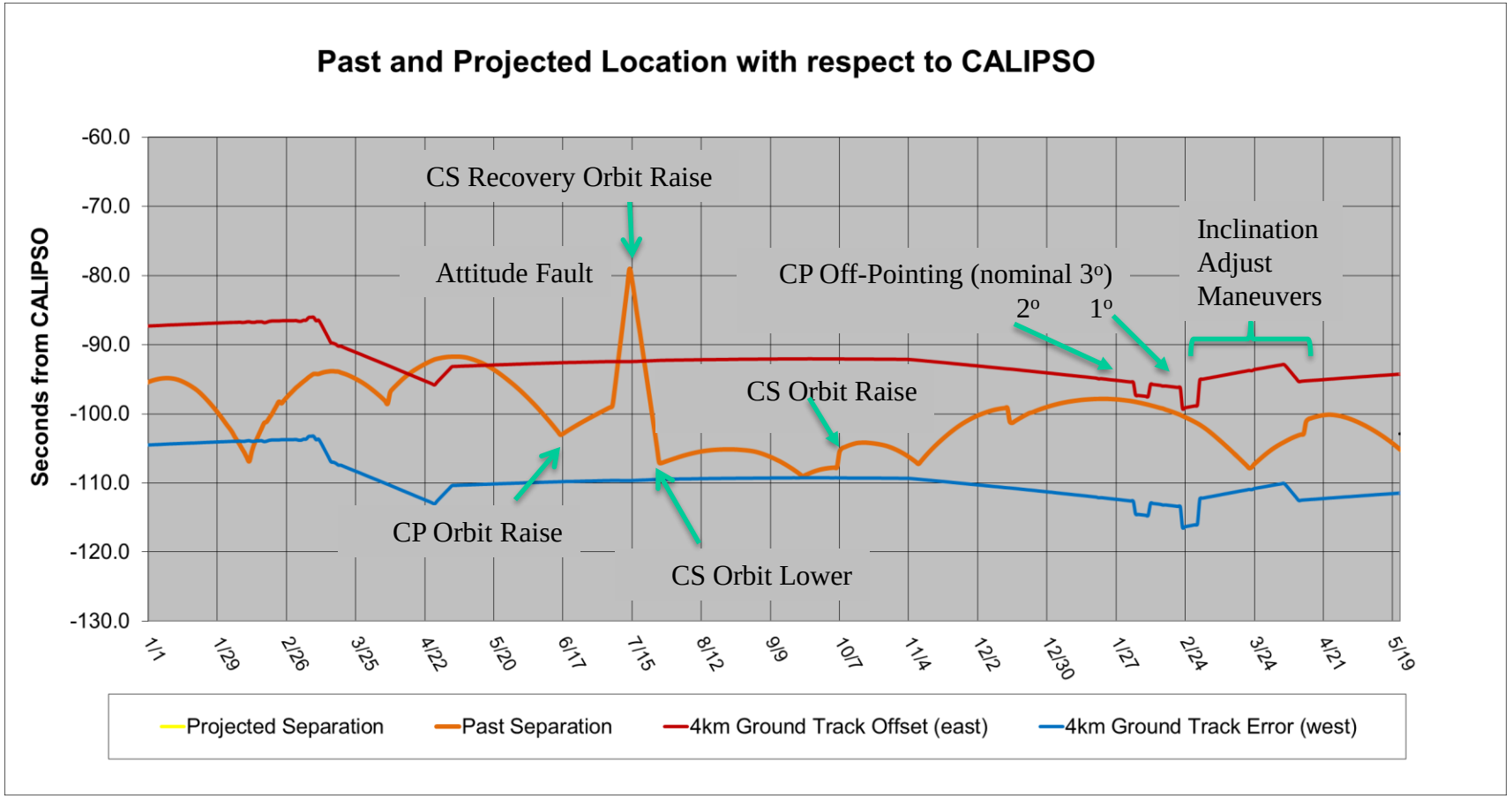
- Fly in Constellation Control Box
  - 100% compliance since last MOWG



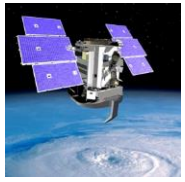
# Recent Performance



- Aim for 4km ground track overlap with CALIPSO 90% of the time
  - 100% compliance since last MOWG



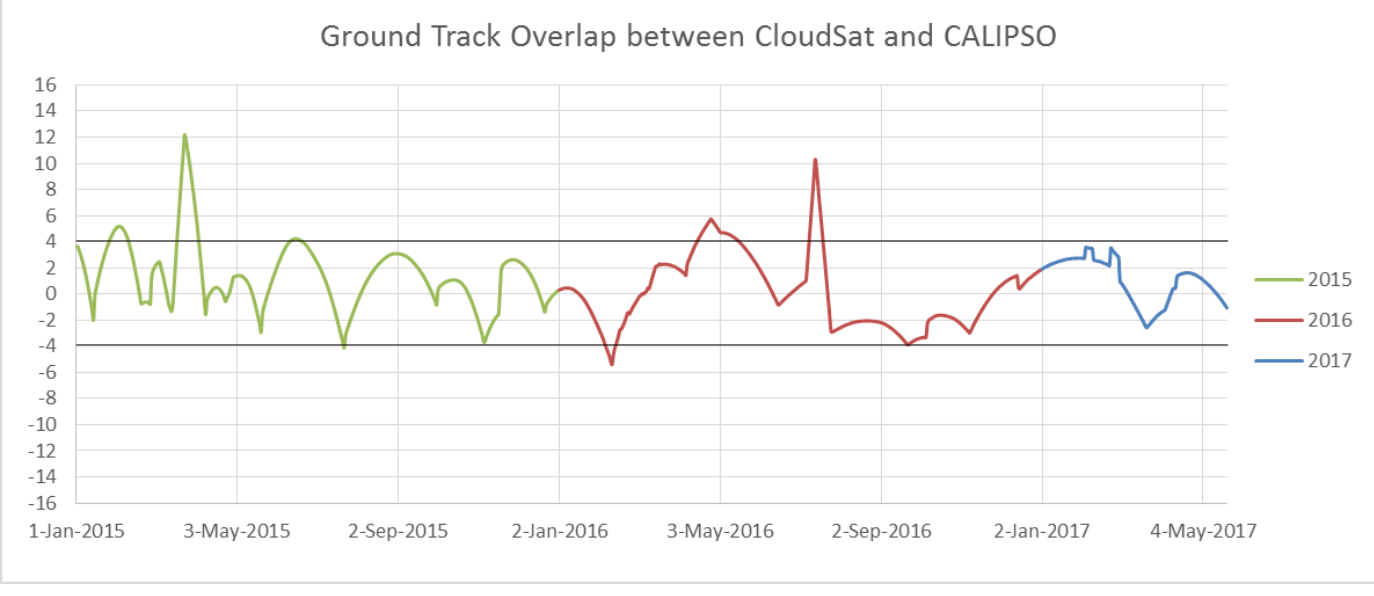
# Overall Status



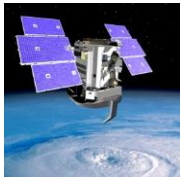
**During 2016, maintained 4km overlap at the equator approximately 87% of the time**

- Failed burn, inclination adjust campaign, changing solar activity resulted in loss of ground track overlap
- Ground track overlap improves away from the equator

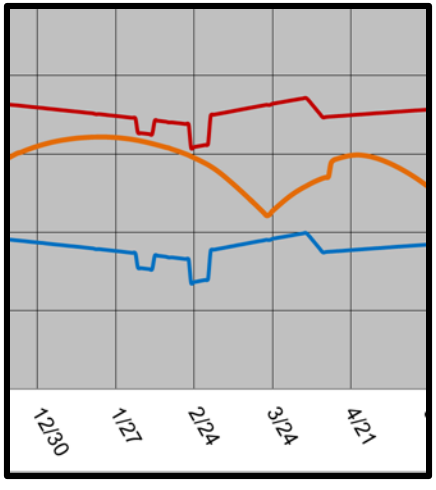
**Since the start of 2017, CloudSat has maintained 4km overlap at the equator 100% of the time**



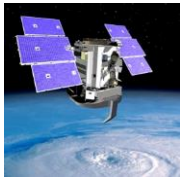
# 2017 Inclination Adjust Maneuvers



- **Inclination Adjust Maneuver #1: 22 February 2017**
  - Desired delta-V: -2.75 m/sec
  - Achieved delta-V: -2.768 m /sec
  - Inclination change: -0.021137 deg
  - SMA change = 1.85 m
  - Percent error = 0.66% (over performance)
- **Inclination Adjust Maneuver #2: 11 April 2017**
  - Desired delta-V: -2.06 m/sec
  - Achieved delta-V: -2.0599 m/sec
  - Inclination change: -0.015876 deg
  - SMA change: 1.684 m
  - % error: -0.005% (under-performance)

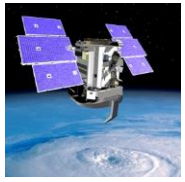


# COLA/RMM Summary (since last MOWG)

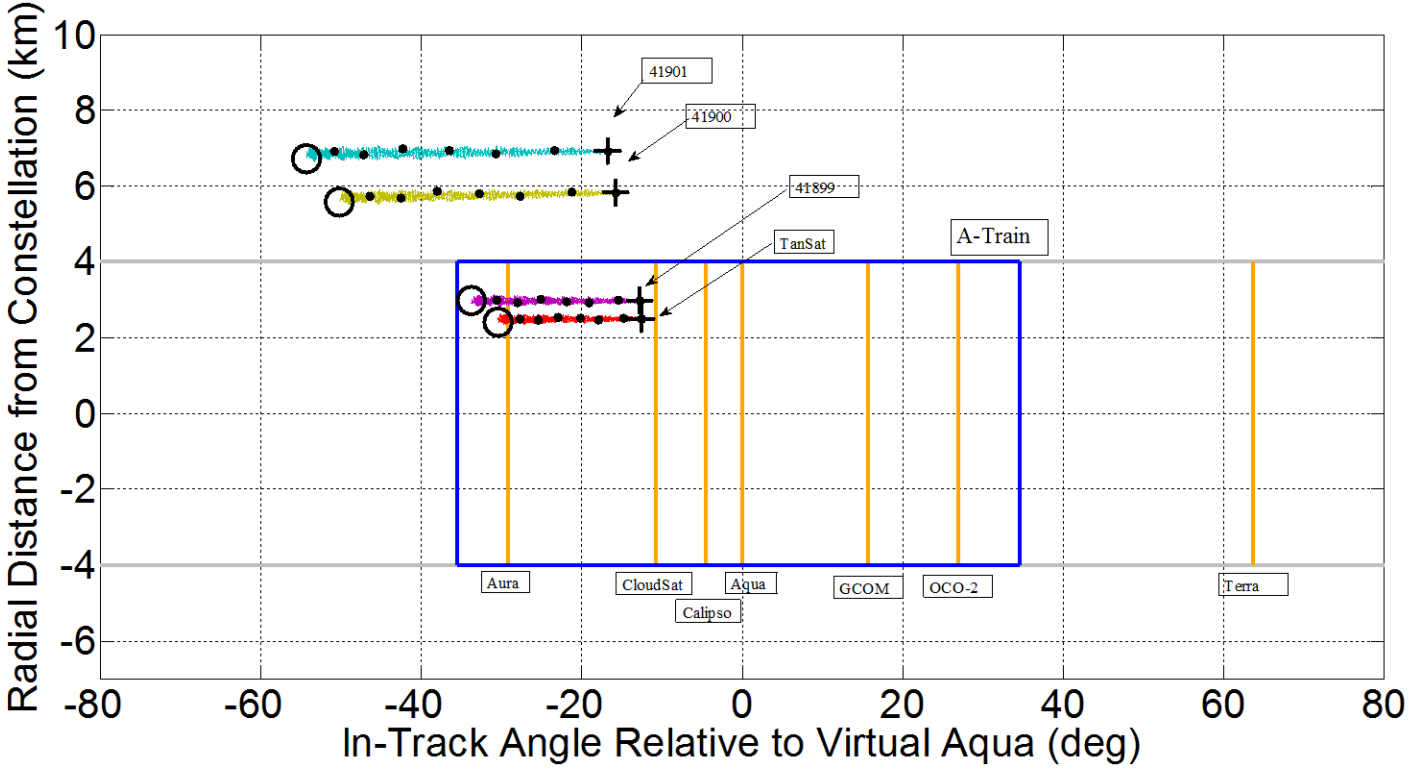


| TCA Date / Time | Object Number | Object ID | First Identified On (Report Generation Time) | Initial / Highest Pc | Highest Level of Action Taken |
|---|---|---|---|---|---|
| 11/16/2016 21:28 | 35933 | BEESAT | 11/10/2016 2:36 | 2.04E-03 | T3 - Conducted preliminary burn planning |
| 4/25/2017 02:55 | 32166 | FENGYUN 1C DEB | 04/21/2017 7:22 | 2.25E-05 | No action taken |
| 5/4/2017 15:19 | 41898 | TANSAT | 04/27/2017 23:33 | 0 | No action taken |
| 5/24/2017 06:23 | 32233 | FENGYUN 1C DEB | 05/18/2017 23:32 | 4.83E-05 | T1/T2 - Requested / received additional CARA Information |

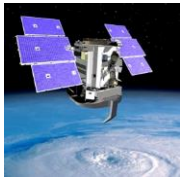
# TanSat Crossing



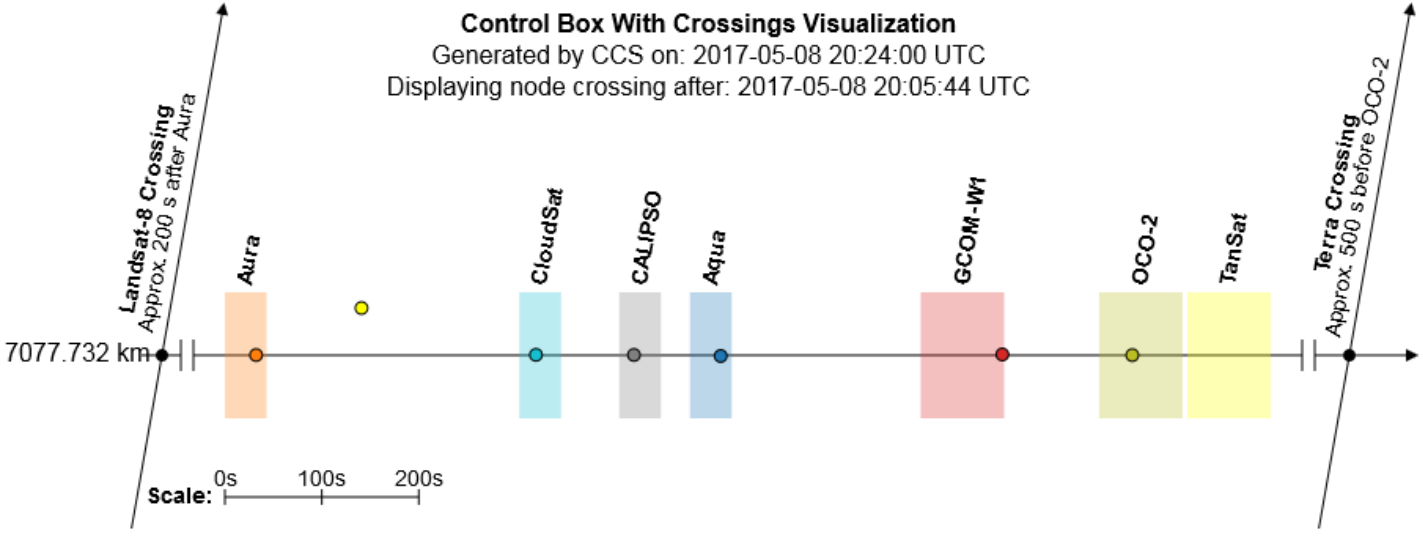
- On 21 December 2016, the Chinese launched the TanSat satellite into the vicinity of the A-Train (near CloudSat's in-track position, but 2km above)
- TanSat has been drifting above the A-Train ever since



# TanSat Crossing

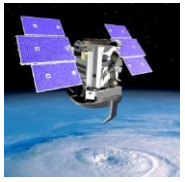


- On 4 May 2017, TanSat came within about 4.5km of CloudSat
  - Pc remained at zero
  - While this was not a particularly close conjunction, it is the closest TanSat has been to an A-Train satellite thus far
- Next projected crossing is in August 2017
- We continue to monitor TanSat with both the Air Force and NASA



# Anomalies

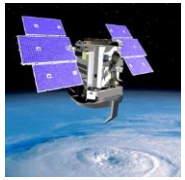
*(Since the last MOWG)*



## Reaction Wheel #1 "Stick-tion" Event – 2 June 2017

- Reaction Wheel #1 began showing signs of "stick-tion" on Friday 2 June 2017
  - ✓ Events were evident when wheel speed rolled through zero crossing
  - ✓ Attitude errors tripped yellow limits, but remained far from red limits
- Friction became worse on Saturday 3 June 2017, so the spacecraft was commanded to Sun-Point-Spin (SPS)
  - ✓ This is a stable and power safe mode, in which to remain while recovery efforts are under way
  - ✓ The Cloud Profiling Radar (CPR) and reaction wheels are off
- All other flight systems are nominal, however science observations are not possible in SPS
- Neither the A-Train Exit Criteria nor any fault protection limits were triggered
- Experts advise that running wheel #1 up to 3000-5000 RPMs for several hours is the recommended coarse of action for resolution
  - ✓ Engineers at Ball Aerospace are currently developing and testing the sequence needed to perform the spin-up
- The spacecraft will remain in SPS, while anomaly recovery efforts continue

# Plans



## Battery Management

- Continue to monitor performance improvement with MMKI gentle charging
- Continue to perform weekly battery health checks

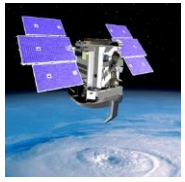
## Special Studies / Operational Improvements

- Continue to look at alternate attitudes that will keep CPR warmer
  - ✓ Goal is to reduce the stability heater on time in eclipse
  - ✓ Thermal analysis is in progress
- Alternate “canned” COLA Maneuver location
- Update pre-loaded Exit Burn Blocks
  - ✓ Updated annually following the Inclination Maneuver Campaign
- Sun Sensor Calibrations
  - ✓ Tool has been completed / now running analyses
- Magnetometer Calibrations
  - ✓ Tool is running / completing sanity checks on results
- Update EIK Switch blocks to incorporate MMKI charging

## Operational / Contingency Enhancements

- MMSOC Data Distribution System (DDS) Implementation
- 3 Reaction Wheel Contingency Plans and Tables
- Contingency On-Orbit Handbook Updates
- Preparation for CPR EIK Switch Over

# Summary



**Daylight Only Operations (DO-Op) and science data collection continue**

- DO-Op requires continues to provide a very robust operating mode

**The Spacecraft and Cloud Profiling Radar continue to operate nominally**

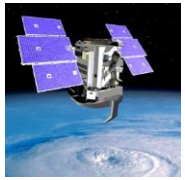
- There has been no loss of redundancy in the past year
- CPR experienced 1 HPA "Trip" in February (1st one since Nov '14)
- Battery health checks were suspended for seasonal loads and now continue on a weekly basis (1 orbit only)
- MMKI battery charging has shown proven results
- SASSI battery charging was discontinued in June 2017
- Magnetic Model was updated on the S/C in April 2017

**Reaction Wheel 1 Spin-Up / Anomaly Recovery is underway**

- The anomaly did not trigger the A-Train Exit Criteria
- The S/C is in SPS and Science operations remain suspended
- Anticipate that spinning-up RWA-1 will return it to nominal operations

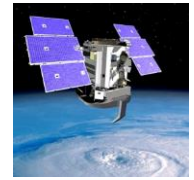
**The annual A-Train Inclination Maneuver Campaign has been completed**

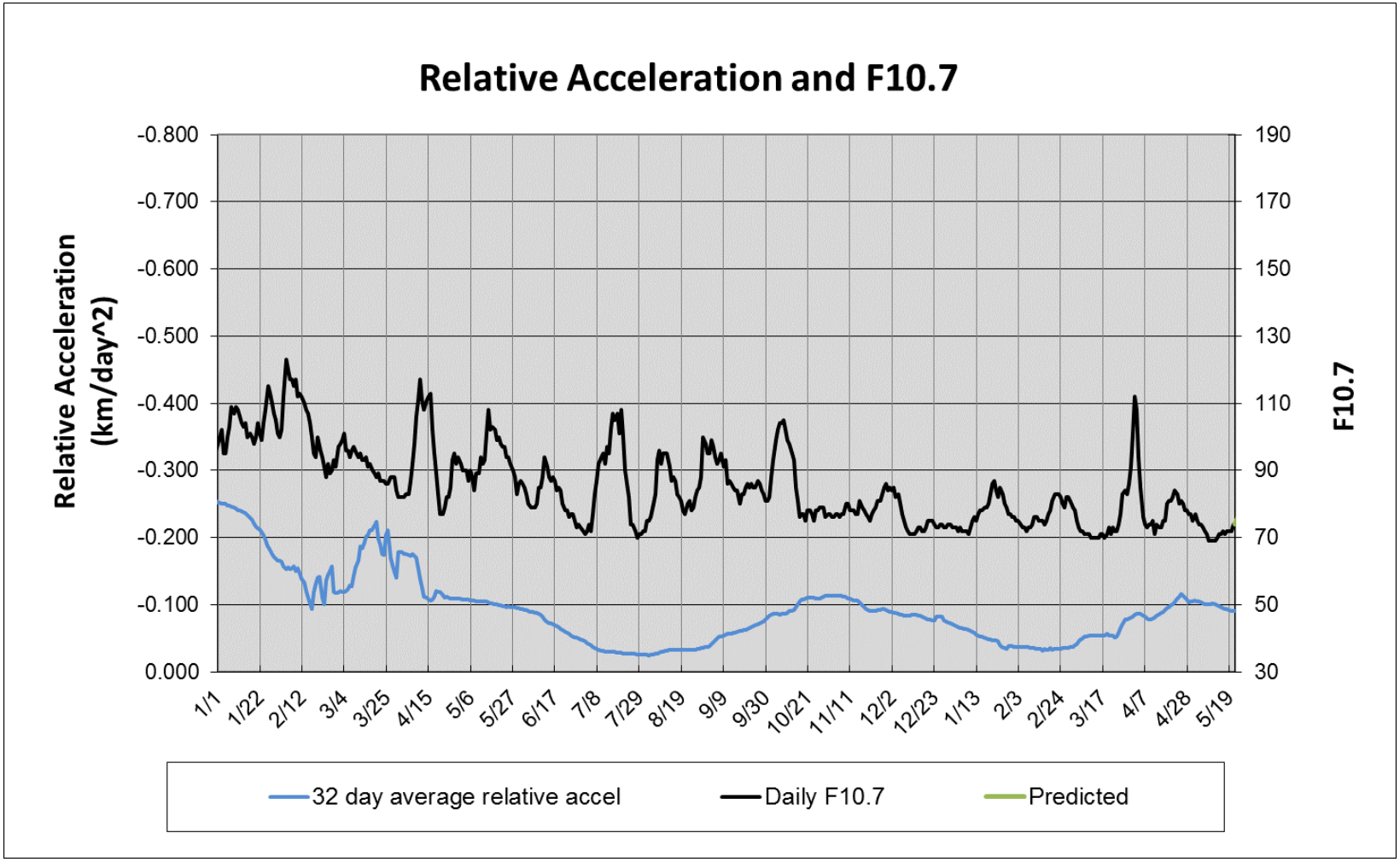
- 1st Inclination Decrease was on 22 February 2017
- 2nd Inclination Decrease is scheduled for 11 April 2017



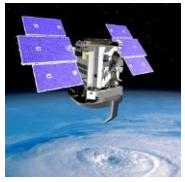
# Back-Up Charts

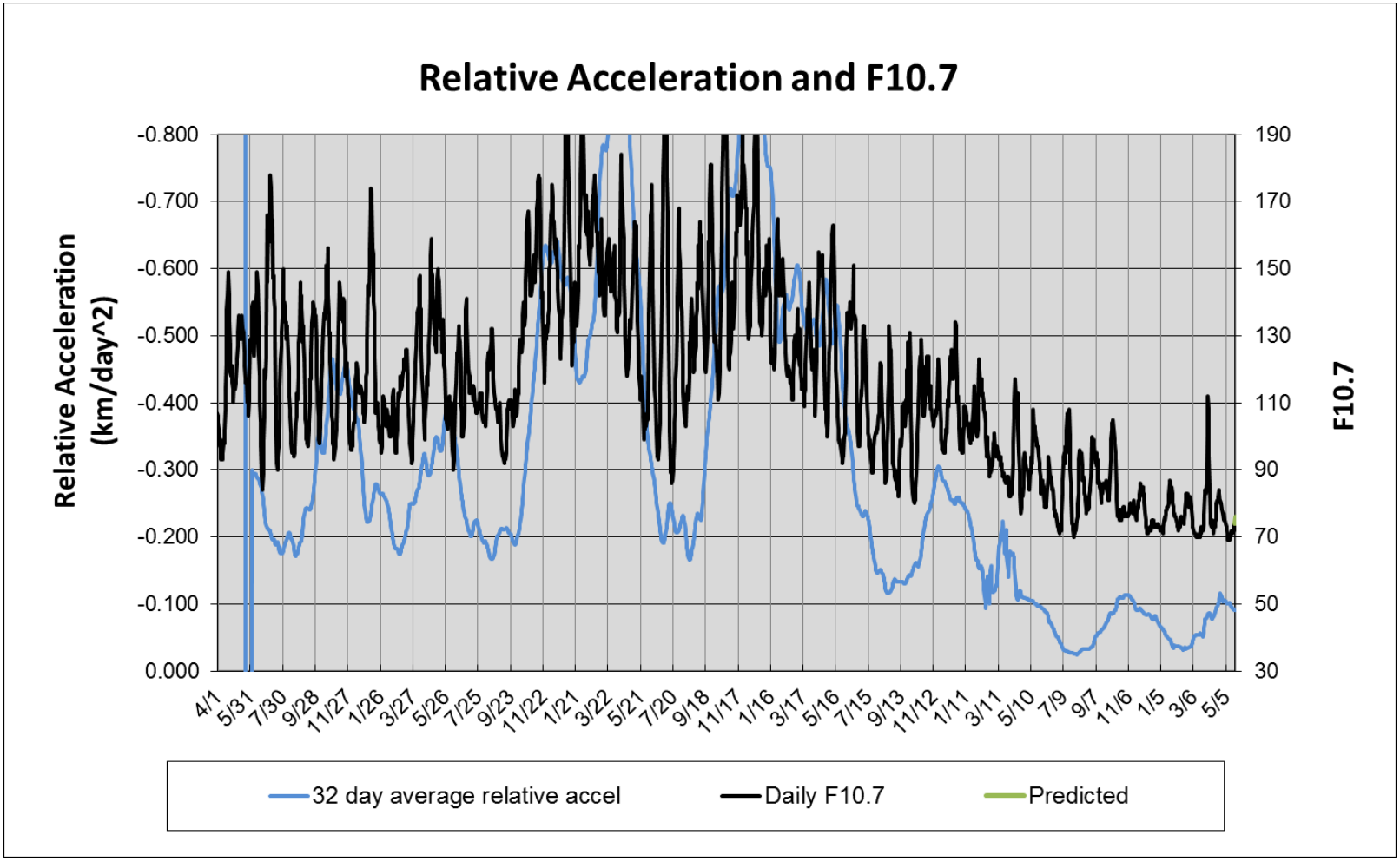
# Solar Data



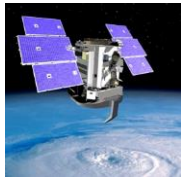

Relative Acceleration and F10.7
Relative Acceleration (km/day^2)
F10.7
-0.800
-0.700
-0.600
-0.500
-0.400
-0.300
-0.200
-0.100
0.000
190
170
150
130
110
90
70
50
30
1/1
1/22
2/12
3/4
3/25
4/15
5/6
5/27
6/17
7/8
7/29
8/19
9/9
9/30
10/21
11/11
12/2
12/23
1/13
2/3
2/24
3/17
4/7
4/28
5/19
32 day average relative accel
Daily F10.7
Predicted

# Solar Data (Since 4/1/2012)



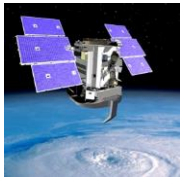


# Maneuver History



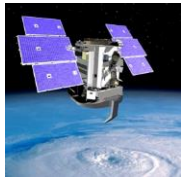
- In 2015 CloudSat conducted 15 *intentional* maneuvers
  - 8 orbit raises (for drag make-up)
  - 4 orbit lowers (for ground track overlap maintenance)
  - 1 risk mitigation (COLA) maneuver (also functioned as an orbit lower for ground track maintenance)
  - 2 inclination decreases as part of the yearly inclination adjust campaign
  - 1 EMC firing
- In 2016 CloudSat conducted 11 maneuvers
  - 5 orbit raises (for drag make-up)
  - 4 orbit lowers (for ground track overlap maintenance)
  - 2 inclination decreases as part of the yearly inclination adjust campaign
- In 2017 to date, CloudSat conducted 4 maneuvers
  - 1 orbit raise (for drag make-up)
  - 1 orbit lower (for ground track overlap maintenance)
  - 2 inclination decreases as part of the yearly inclination adjust campaign

# COLA/RMM Summary 2016



| TCA Date / Time | Object Number | Object ID | First Identified On (Report Generation Time) | Initial / Highest Pc | Highest Level of Action Taken |
|---|---|---|---|---|---|
| Multiple | 32072 | CBERS 1 DEB | 01/02/2016 15:24 | Various | No action taken |
| 2/22/2016 12:25 | 30597 | FENGYUN 1C DEB | 02/18/2016 4:34 | 1.07E-05 | No action taken |
| 2/29/2016 16:15 | 41179 | ORBCOMM FM 114 | 02/27/2016 19:02 | 9.24E-05 | T1/T2 - Requested / received additional CARA Information |
| Multiple | 35932 | SWISSCUBE | 04/03/2016 14:02 | Various | No action taken |
| 9/16/2016 01:42 | 34308 | COSMOS 2251 DEB | 09/12/2016 23:24 | 4.51E-05 | T3 - Conducted preliminary burn planning |

# Summary



- CloudSat continues to maintain its formation flying mission
  - Only one instance of ground track overlap loss since the last ops review (due to the attitude fault that resulted in a failed burn)
  - Since the last ops review, no risk mitigation maneuvers due to conjunctions were required
  - CloudSat successfully completed the 2017 Spring Inclination Adjust campaign
- CloudSat continues to work with the Air Force and NASA to monitor TanSat crossings