International Earth Science Constellation
Mission Operations Working Group (MOWG)
June 5-7, 2019
Aura Spring 2019 IAM Series Results
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Agenda

- Recap Aura 2019 Inclination Adjust Maneuver (IAM) Campaign
  - Series Summary
  - Maneuver Results
  - Post-2019 Mean Local Time (MLT) Phasing Evolutions
- Aura's IAM Performance Trends
- 2020 IAM Campaign Dates and Planning
- Aura Latest Lifetime MLT Predictions
- Summary

Aura Spring 2019 Series Summary

- Aura performed 4 inclination maneuvers between March 6th and April 10th

- Aura's Reaction Wheel Assembly (RWA) was successfully utilized to slew to the desired angle for the inclination maneuvers

- Since there were no available on-orbit maneuvers to trend parameters, simulation data was used to predict IAM#59

  - This maneuver achieved less change in inclination (delta-INC, -12%) and more change in semi-major axis (delta-SMA, additional 17.6m) than predicted, requiring longer burn durations and more negative yaw angle for the remaining maneuvers to maintain MLT phasing and Ground Track Error (GTE)

- The remaining maneuvers each used the performance of the previous maneuver as the prediction

  - Minor adjustments to commanded yaw angle and burn duration were made to maintain GTE and MLT phasing using updated Aqua predictions

- The last two IAMs of the series were delayed two weeks to avoid high-risk conjunctions

Aura Series Results

Inc #	Date	Burn Duration (sec)	Commanded Yaw (deg)	Achieved Yaw (deg)		Delta Inclination (deg)		Delta RAAN* (deg)	
				Predicted	Definitive	Predicted	Definitive	Predicted	Definitive
59	Mar 6	383.0	-76.5	-75.82	-75.13	-0.00809	-0.00712	0.00447	0.00445
60	Mar 13	450.0	-77.5	-76.13	-75.98	-0.00840	-0.00828	0.00516	0.00515
61	Apr 3	457.0	-79.0	-77.48	-77.52	-0.00842	-0.00834	0.00526	0.00525
62	Apr 10	473.0	-77.5	-76.02	-77.54	-0.00859	-0.00861	0.00544	0.00543
*Right Ascension of the Ascending Node (RAAN)						**Total:**	**-0.03234**		

- Aura's achieved delta-INC for the entire series was 0.31% HOT, based on the December 2018 MOWG plan (-0.03224 deg)

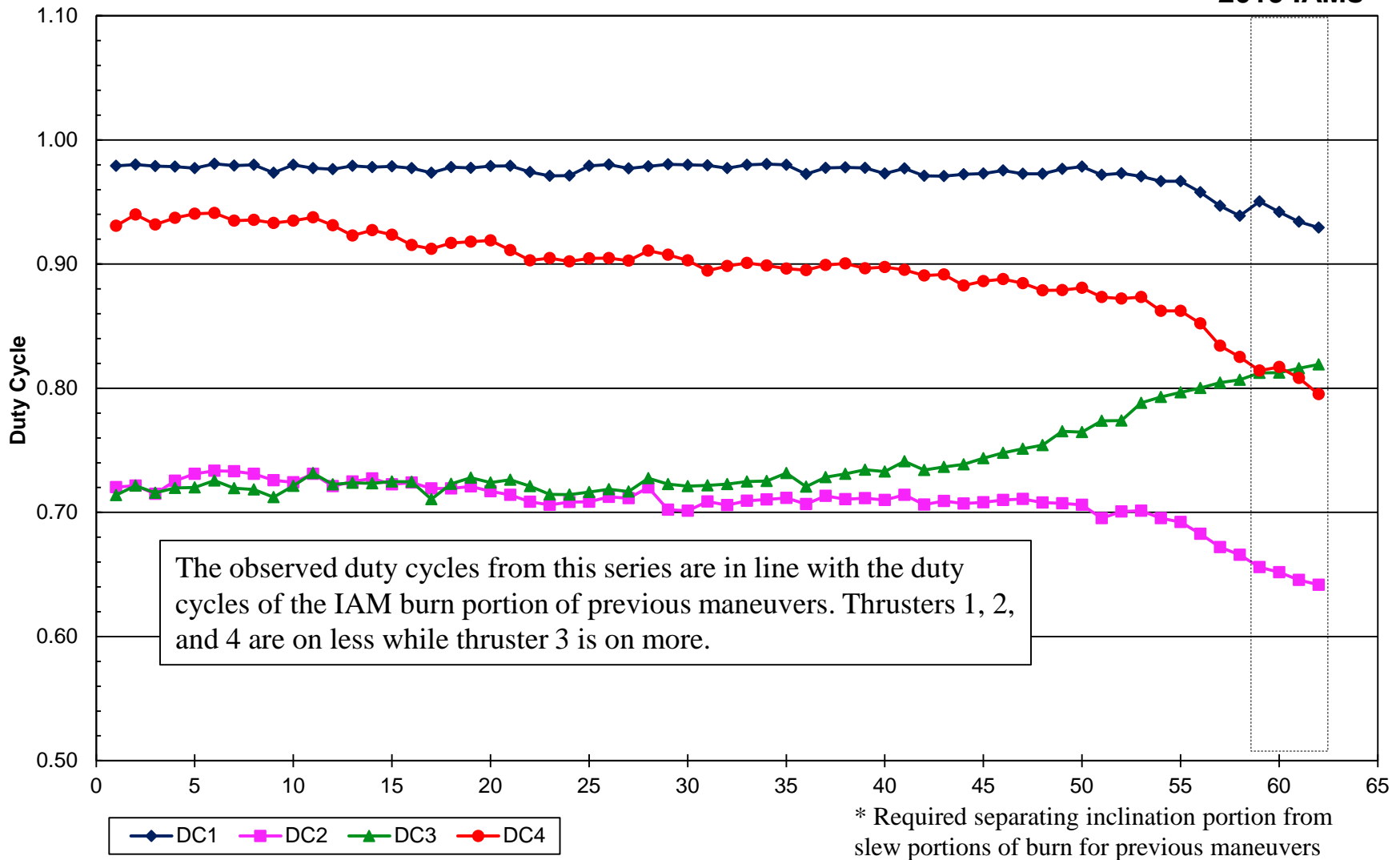## Aura Post-2019 Series Predicted MLT Phasing
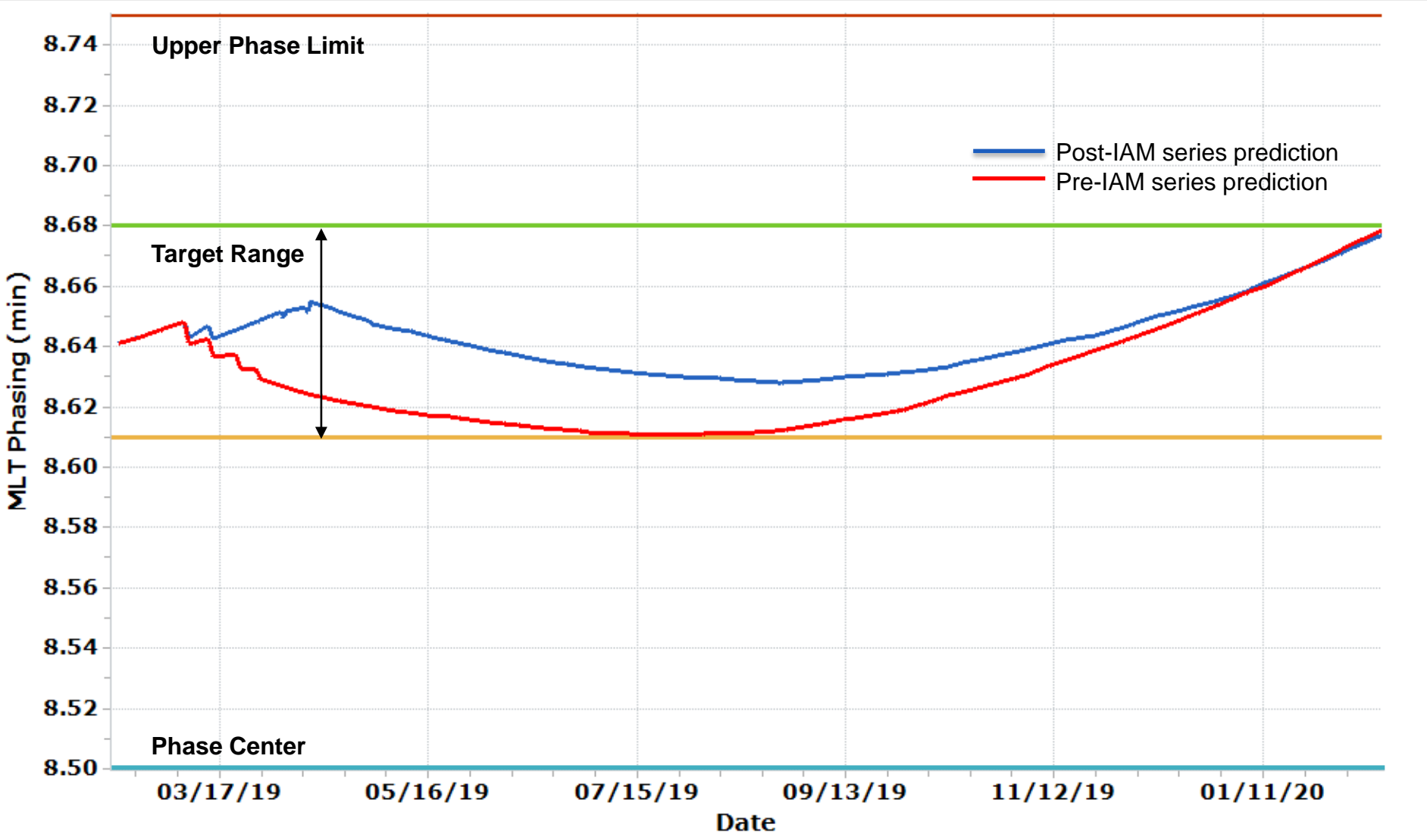
Aura Spring 2019 Series Performance Trends

- The thruster duty cycles (DC1-4) and maneuver thrust scale factor for all maneuvers in this series were similar to previous, thruster-slewed, maneuvers
- While the simulations did not accurately model the thrusters, resulting in the poor performance, the attitude during the slews matched what was observed on-orbit
- The roll and pitch attitude errors during the burn have continued the trend of previous maneuvers as well
- Yaw error from telemetry for IAM#59-61 of this series was similar to previous IAMs but IAM#62 differed drastically
  - Additional trended yaw offset: calibrated yaw is the yaw angle necessary to achieve the observed delta-SMA
  - Investigation into IAM#62 performance is on-going
- The slew portions of this series used no fuel which increased the efficiency of the maneuvers
  - Efficiency is in terms of delta-INC per kilogram of fuel consumed

Aura's IAM Performance

Inclination Burn* Thruster Duty Cycles

The observed duty cycles from this series are in line with the duty cycles of the IAM burn portion of previous maneuvers. Thrusters 1, 2, and 4 are on less while thruster 3 is on more.

Legend: DC1, DC2, DC3, DC4

* Required separating inclination portion from slew portions of burn for previous maneuvers
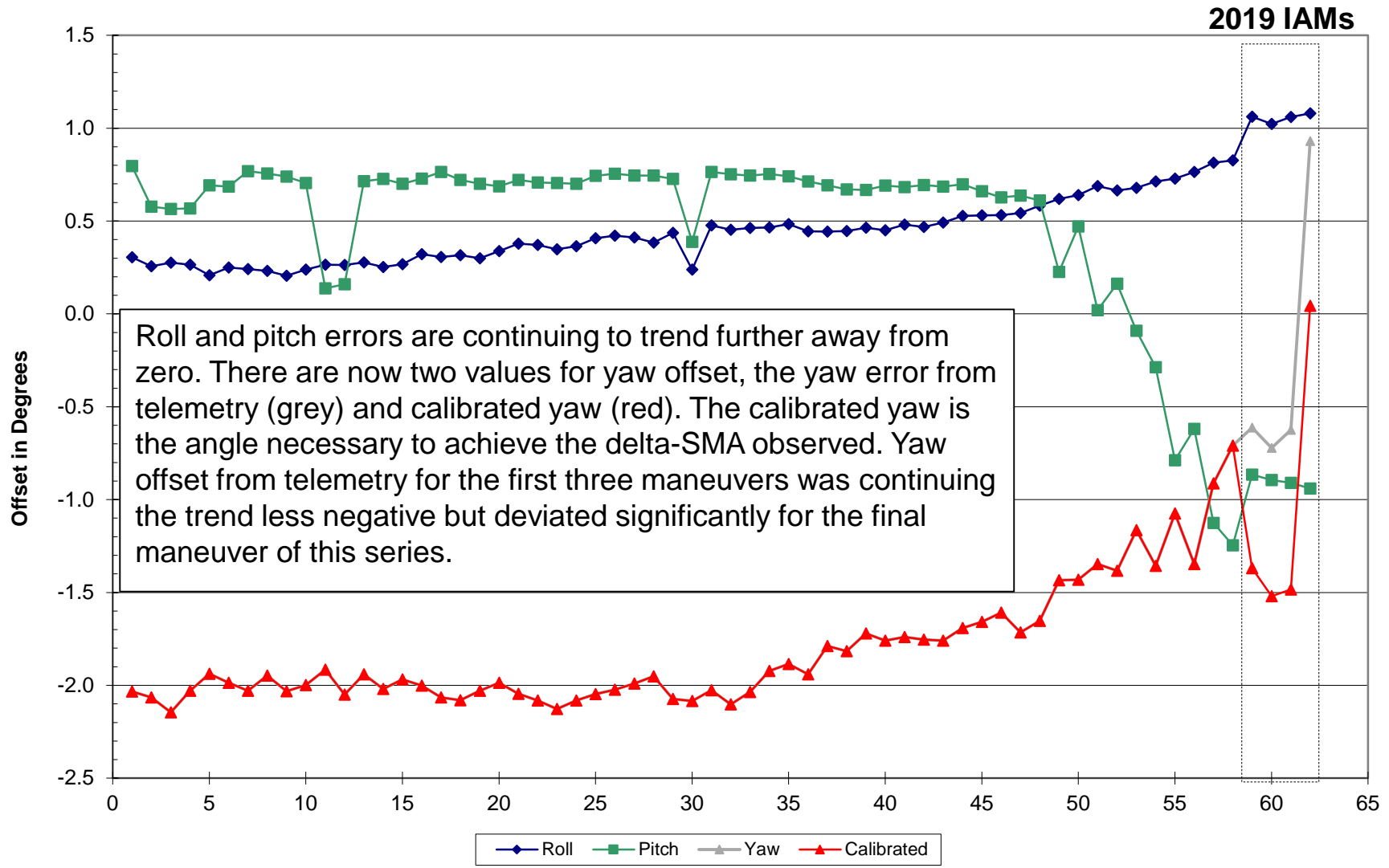
Aura's IAM Performance

- The on-orbit attitude of IAM#59 matched well with the simulation (predicted) attitude

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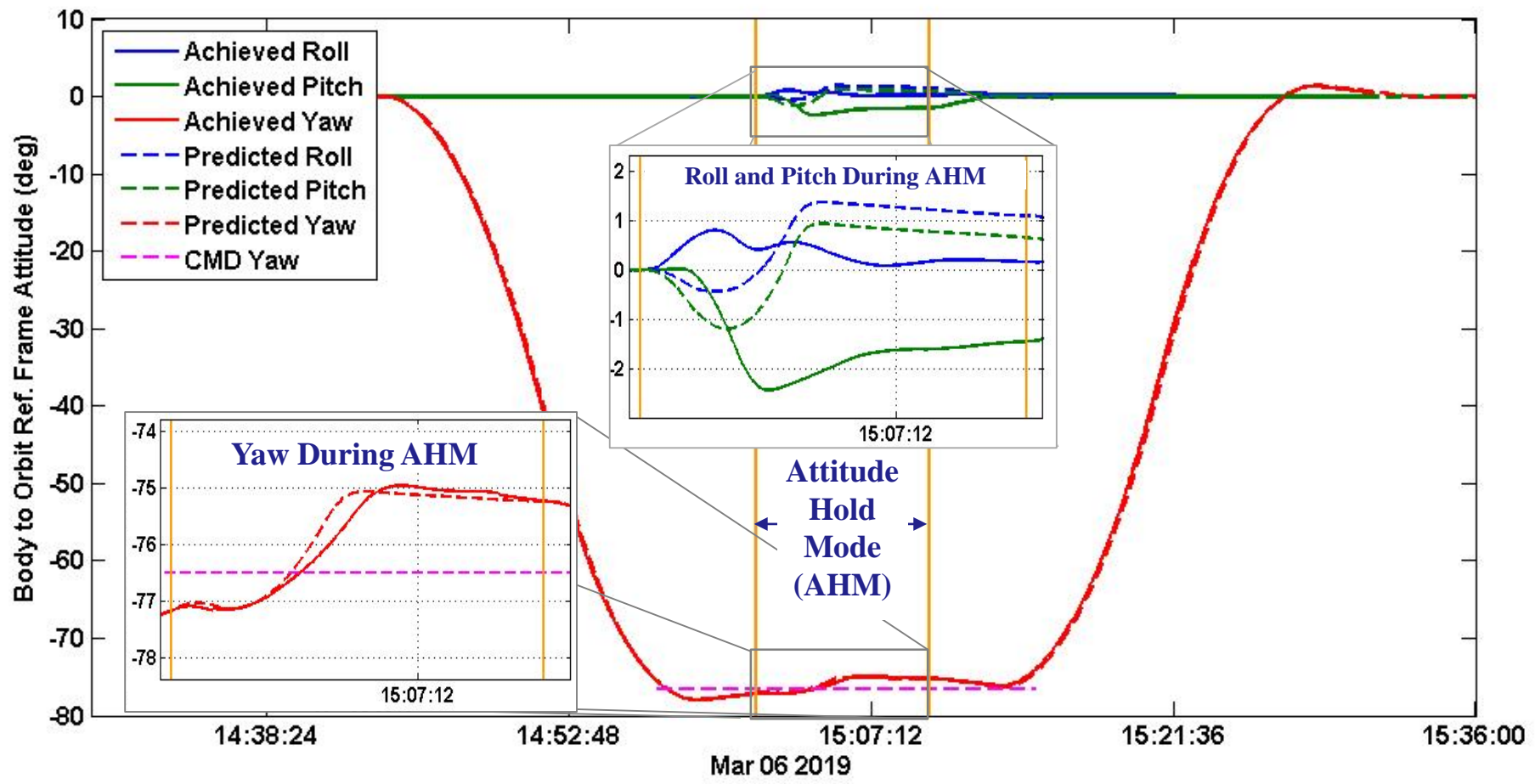
Aura's IAM Performance
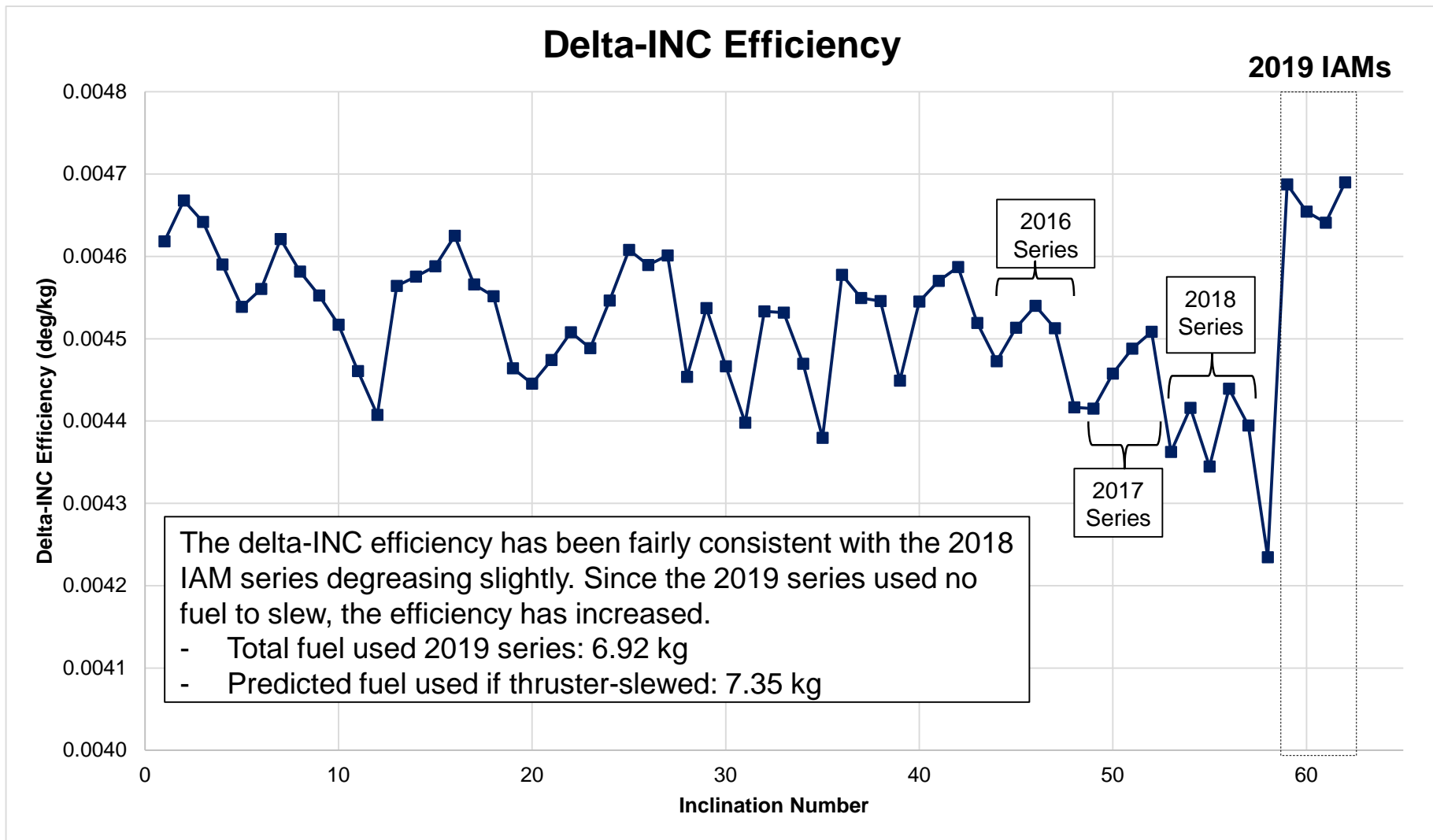

Aura Average Roll, Pitch, and Yaw Error during INC

Roll and pitch errors are continuing to trend further away from zero. There are now two values for yaw offset, the yaw error from telemetry (grey) and calibrated yaw (red). The calibrated yaw is the angle necessary to achieve the delta-SMA observed. Yaw offset from telemetry for the first three maneuvers was continuing the trend less negative but deviated significantly for the final maneuver of this series.

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Aura's IAM Performance

Delta-INC Efficiency

2019 IAMs

2016 Series

2018 Series

2017 Series

The delta-INC efficiency has been fairly consistent with the 2018 IAM series degreasing slightly. Since the 2019 series used no fuel to slew, the efficiency has increased.
- Total fuel used 2019 series: 6.92 kg
- Predicted fuel used if thruster-slewed: 7.35 kg

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Aura Spring 2020 IAM Campaign Planning

- The Aura Spring 2020 IAM plan consists of 6 inclination maneuvers
  - Again plan on using RWA to slew
- Aura's predicted ideal burn date occurs March 12, 2020
- Proposed plan has 3 maneuvers occurring before the ideal burn date, and 3 after
  - February 26 (IAM #63)
  - March 4 (IAM #64)
  - March 11 (IAM #65)
  - March 18 (IAM #66)
  - March 25 (IAM #67)
  - April 1 (IAM #68)
- Dates are set so Aura maneuvers a day before Aqua

Mission Operations Working Group
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Proposed Aqua/Aura 2020 Maneuver Schedule

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
February 23	24	25	26 Aura IAM#63	27 Aqua IAM#66	28	29
March 1	2	3	4 Aura IAM#64	5 Aqua IAM#67	6	7
8	9	10	11 Aura IAM#65	12 ** Aqua IAM#68	13	14
15	16	17	18 Aura IAM#66	19 Aqua IAM#69	20*	21
22***	23	24	25 Aura IAM#67	26 Aqua IAM#70	27	28
29	30	31	**April** 1 Aura IAM#68	2 Aqua IAM#71	3	4
5	6	7	8 Aura Back-up	9 Aqua Back-up	10	11
12	13	14	15	16	17	18

*Spring Equinox on March 20
**Aura Ideal Date on March 12
***Aqua Ideal Date on March 22
Note: Golden Week in Japan starts April 28

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Aura Predicted 2020 Maneuver Performance

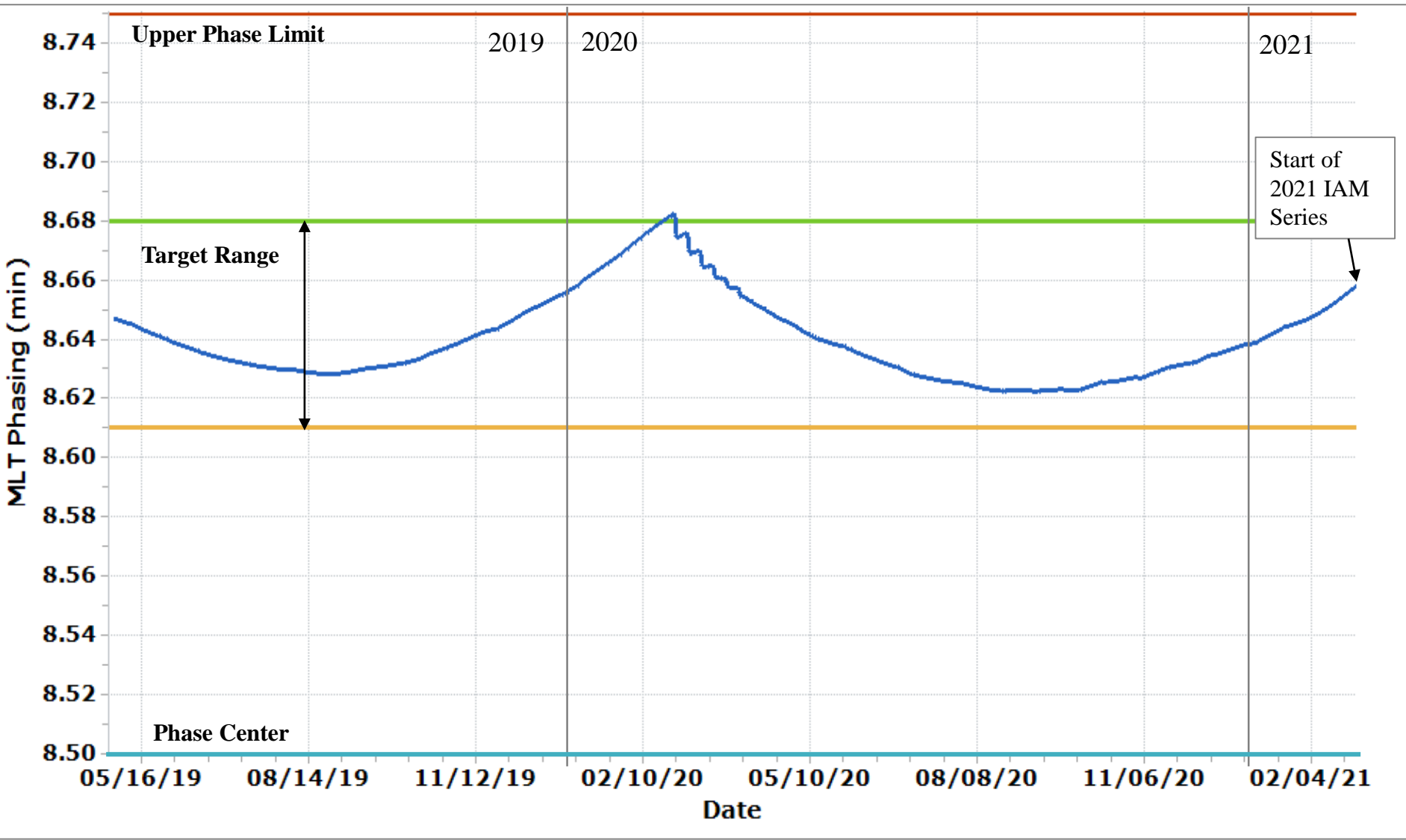| Inc #	Date	Commanded Yaw* (deg)	Duration (sec)	Delta SMA** (m)	Delta Inc (deg)	Delta RAAN (deg)
63	Feb 26			-9.01	-0.00773	-0.00001
64	Mar 04			-8.98	-0.00771	-0.00001
65	Mar 11	-77.5	421.0	-8.95	-0.00768	-0.00001
66	Mar 18			-8.92	-0.00766	-0.00001
67	Mar 25			-8.90	-0.00764	-0.00001
68	Apr 01			-8.88	-0.00762	-0.00001
			Total:		**-0.04603**	-0.00006

*Preliminary angles
**Semi-Major Axis (SMA)

- Trending has not been developed for RWA slewed maneuvers, so performance of IAM#61 was used in predictions

Aura Spring 2020 IAM Campaign Planning

- Aura is predicted to exit its "mission goal" MLT phasing limit prior to the 2020 IAM series
  - Predicted to exit on February 21
  - 2020 IAM series: February 26 – April 01
  - Predicted to re-enter February 27
- Correcting the predicted exit is straightforward
  - Violation can be avoided by executing 4 Drag Make-up maneuvers (DMUs) at descending node
  - Descending node DMUs will help Aura maintain the tight MLT phasing box and will reduce the IAM burn durations in the 2020 IAM series
- Aura is predicted to be near the center of the MLT phasing control box at the start of the 2021 IAM series

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Predicted Pre- and Post-2020 IAM Aura MLT Phasing
DMUs at Frozen Orbit Locations

Predicted 2020 IAM Series Aura MLT Progression
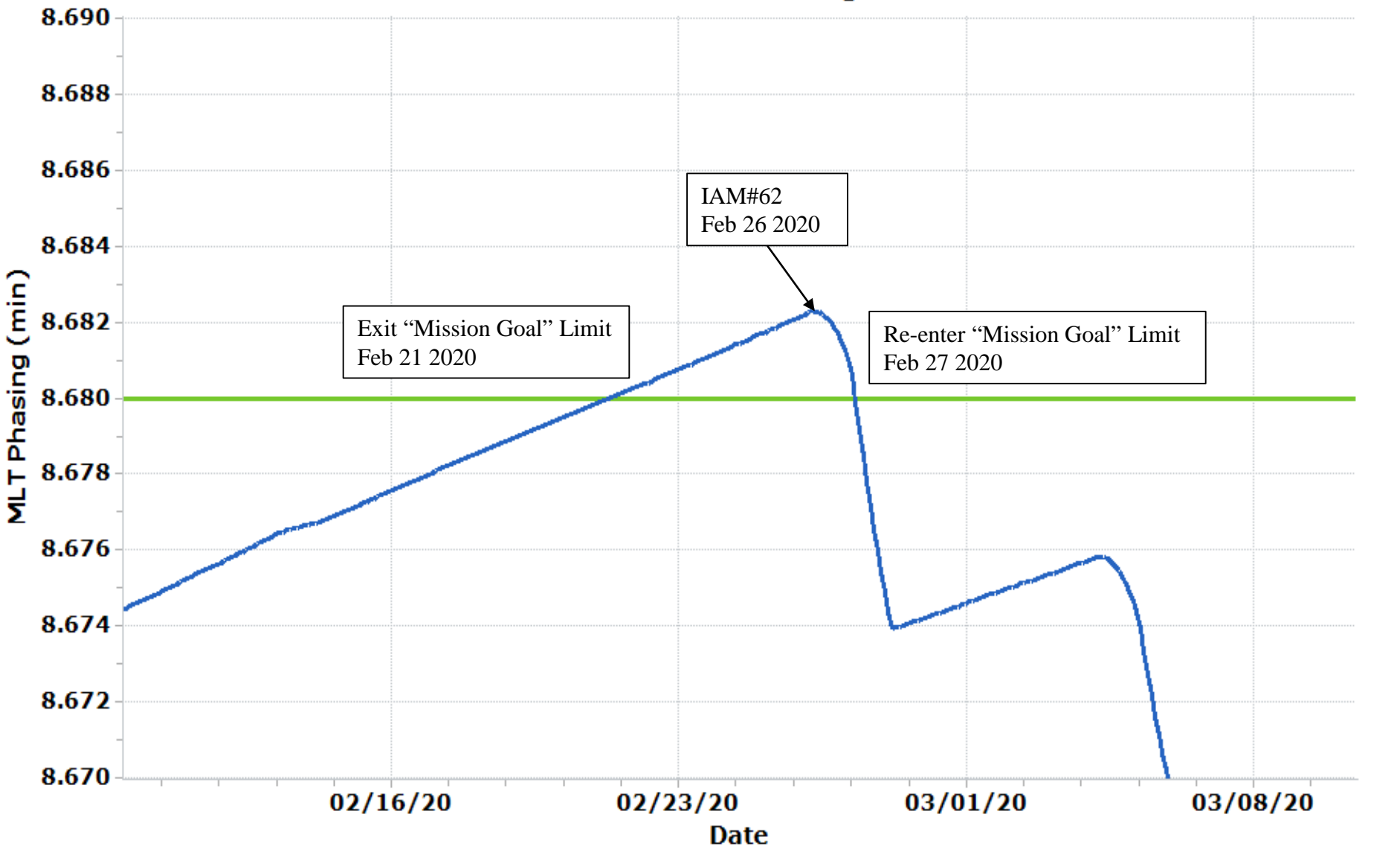
Aura Predicted 2020 Maneuver Performance
Descending Node DMU Scheme

Inc #	Date	Commanded Yaw* (deg)	Duration (sec)	Delta SMA (m)	Delta Inc (deg)	Delta RAAN (deg)
63	Feb 26			-8.97	-0.00769	-0.00001
64	Mar 04			-8.93	-0.00767	-0.00001
65	Mar 11	-77.5	419.0	-8.90	-0.00765	-0.00001
66	Mar 18			-8.88	-0.00762	-0.00001
67	Mar 25			-8.86	-0.00760	-0.00001
68	Apr 01			-8.84	-0.00758	-0.00001
			Total:		**-0.04581**	-0.00006

*Preliminary angles

- Trending has not been developed for RWA slewed maneuvers, so performance of IAM#61 was used in predictions

Predicted Pre- and Post-2020 IAM Aura MLT Descending Node DMU Scheme
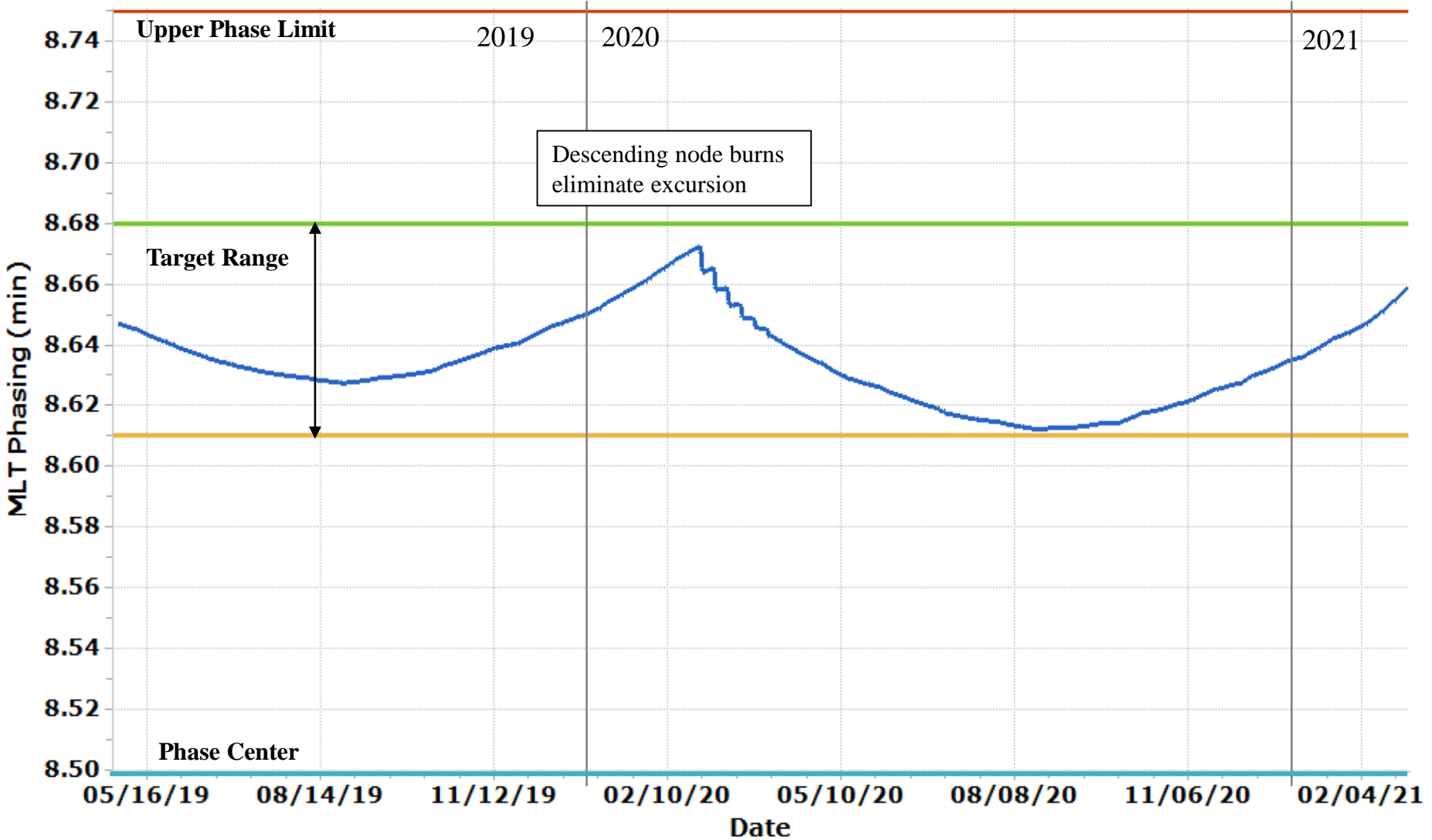
Summary

- During the 2019 IAM series, Aura successfully utilized the RWA to slew to the necessary angle

- The 2020 IAM series will have 6 maneuvers and is predicted to keep Aura near the center of the MLT phasing control box prior to the 2020 series

- The predicted 2020 IAM series performance is likely to be updated after trending method developed and further analysis of the observed 2019 IAM series performance

Special Thanks To

- Elena Trenholme
  - Elena's tireless dedication helped pave the way for the successful RWA IAM series. She helped identify software updates and process improvements to help prepare the FDS and ensure each maneuver was executed flawlessly.
  - Elena's careful planning and analysis throughout the series helped the FDS team adjust so Aura maintained ground track error throughout the series and predicted long-term MLT phasing requirements
- The FDS Team
  - The entire team worked very hard to support both Aura and Aqua throughout the series.