International Earth Science Constellation
Mission Operations Working Group
December 6-8, 2017
Aqua/Aura Inclination Adjust Maneuver Series
Spring 2018 Planning
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Mission Operations Working Group
December 6-8, 2017

Agenda

• 2017 Drag Make-Up (DMU) Maneuver Strategy
• 2018 Inclination Adjust Maneuver (IAM) Campaign Planning
  – Spring 2017 Mission Operations Working Group (MOWG) Summary
  – New Trending Overview
  – Aqua and Aura Maneuver Schedule
  – Predicted Aqua and Aura Maneuver Performance
• Aqua/Aura 2018-2019 Mean Local Time (MLT) Predictions
• 2018 IAM Campaign Summary

Green text is values for current plan.

Red text is values from previous plans.
2017 Drag Make-up Maneuver Strategy

- Aqua and Aura continue to operate using a hybrid maneuver scheme
- Aqua’s hybrid maneuver scheme (mirror pole and frozen orbit)
  - April – Sept: DMU maneuvers performed at alternating pole locations
  - Oct. – 2018 IAM series: DMU maneuvers performed at argument of latitude that best maintains frozen orbit requirements
- Aura’s hybrid maneuver scheme (descending node and frozen orbit)
  - Maneuvers performed at the descending node to improve MLT phasing
  - Nov. – 2018 IAM series: frozen orbit maintenance maneuvers performed
- With the current low-drag environment, both are using a modified targeting scheme now:
  - A four-week DMU cadence is being utilized for maneuver planning
  - GTE controlled near the top quarter of the control box
  - Allows room to execute Risk Mitigation Maneuvers (RMM) and remain in the control box
- RMM locations are dictated by conjunction timing and geometry
Recap of Spring 2017 MOWG

• At the Spring 2017 MOWG presented (1) change in burn duration for Aqua and (2) Aqua/Aura burn order switched
  – Predicted change in inclination ($\Delta I$) would be less than presented at 2016 MOWG ( -0.04089° )
    • Burn duration needed to increase to 565.0 seconds from 550.0 seconds
    • Predicted $\Delta I$ presented: -0.04083°
    • Schedule: 3-1-1 cadence
      – Each mission performs a maneuver a week for three weeks, then one week off, another week of one maneuver each, a week off, and a final week of one maneuver each
  – Upward Aqua-Aura phasing spikes caused the upper phasing limit to be briefly violated soon after 2018 IAM series
    • Burn order: Aura before Aqua (originally Aqua then Aura)
    • Helps push phasing in the desired direction
Trending Methodology Update

- Previous two IAM series (2016 and 2017), the change in semi-major axis ($\Delta$SMA) and $\Delta$I predictions were less accurate than desired
- Analysis was performed to determine ways to improve our current prediction method
- A new method was developed which identifies the best (statistically significant) parameter combinations to create trends
  - Methodology discussed more thoroughly in separate presentation
- Implemented in latest Lifetime and Decommissioning Analysis Report for each mission and used in predicted performance in this presentation
  - Aqua’s predicted $\Delta$I would increase to -0.04120°
  - Burn duration decreased to 560.0 seconds to better match previous value
    - Predicted $\Delta$I: -0.04086°
    - Duty cycles trended from 550.0 second burn duration
      - Burn duration may change to meet advertised $\Delta$I
The Aqua Spring 2018 IAM plan consists of five inclination maneuvers performed on Thursdays.

- Burn duration: 560.0 seconds
- Aqua’s predicted ideal burn date occurs around March 22, 2018
- Proposed plan has three maneuvers occurring before the ideal burn date and two after:
  - March 1, 2018 (IAM #56)
  - March 8, 2018 (IAM #57)
  - March 15, 2018 (IAM #58)
  - March 29, 2018 (IAM #59)
  - April 12, 2018 (IAM #60)

Note: Performing maneuvers off of the ideal date slightly decreases burn efficiency.
Aura Spring 2018 IAM Campaign Planning

- The Aura Spring 2018 IAM plan consists of five inclination maneuvers performed on Wednesdays
- Burn duration: 398.0 seconds
- Aura’s predicted ideal burn date occurs around March 27, 2018
- Proposed plan has three maneuvers occurring before the ideal burn date and two after
  - February 28, 2018 (IAM #53)
  - March 7, 2018 (IAM #54)
  - March 14, 2018 (IAM #55)
  - March 28, 2018 (IAM #56)*
  - April 11, 2018 (IAM #57)

*ESMO is currently evaluating the execution of an IAM using wheels and may execute IAM#56 in this manner.

**Note:** Performing maneuvers off of the ideal date slightly decreases burn efficiency
Aura IAM#56 (fourth in the series) may be executed using wheels to slew out to the burn attitude and slew back to nominal pointing

These slews will not contribute to the overall inclination change or contribute to the SMA changes.

Therefore the maneuver duration and slew angle will be adjusted to achieve the desired $\Delta I$ (for the phasing relative to Aqua) and altitude change (to maintain the ground track).

The fourth burn was chosen because of the additional time both before and after for additional preparations and/or re-planning for the final burn.
**Proposed Aqua/Aura 2018 Maneuver Schedule**

### Aqua/Aura 2018 Inclination Maneuver Series Schedule

<table>
<thead>
<tr>
<th>Sunday</th>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
<th>Saturday</th>
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<tr>
<td></td>
<td>Aura IAM#53</td>
<td>Aura IAM#55</td>
<td>March 1 Aqua IAM#56</td>
<td>Aqua IAM#57</td>
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<td>Aura IAM#54</td>
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<tr>
<td>28</td>
<td>4</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
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<tr>
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<td>Aura IAM#54</td>
<td>Aqua IAM#57</td>
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<tr>
<td>11</td>
<td>12</td>
<td>13</td>
<td>14</td>
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<td>16</td>
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<tr>
<td>Aura IAM#54</td>
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<td>Aura IAM#55</td>
<td>Aqua IAM#58</td>
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<td>Aura IAM#55</td>
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<tr>
<td>18</td>
<td>19</td>
<td>20 Equinox</td>
<td>21</td>
<td>22 Equinox</td>
<td>23</td>
<td>24</td>
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<tr>
<td>Aura IAM#55</td>
<td></td>
<td></td>
<td>Aqua Ideal Date</td>
<td>Aqua Ideal Date</td>
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<td>Aura IAM#56</td>
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<tr>
<td>25</td>
<td>26</td>
<td>27 Equinox</td>
<td>28 Aqua IAM#56</td>
<td>29 Aqua IAM#59</td>
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<tr>
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<td>Aqua Ideal Date</td>
<td>Aqua IAM#56</td>
<td>Aqua IAM#59</td>
<td></td>
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<tr>
<td>April 1</td>
<td>Easter Sunday</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
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<td>8</td>
<td>9</td>
<td>10</td>
<td>11 Aura IAM#57</td>
<td>12 Aqua IAM#60</td>
<td>13</td>
<td>14</td>
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<tr>
<td>15</td>
<td>16</td>
<td>17</td>
<td>18</td>
<td>19</td>
<td>20</td>
<td>21*</td>
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*Japan Golden Week starts April 29
## 2018 Predicted Maneuver Performance*

<table>
<thead>
<tr>
<th>IAM #</th>
<th>Date</th>
<th>Target Yaw Angle (deg)</th>
<th>Burn Duration (sec)</th>
<th>Delta-V (m/sec)</th>
<th>Delta-SMA (m)</th>
<th>Delta-Inc (deg)</th>
<th>Delta-RAAN (deg)</th>
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<tbody>
<tr>
<td>56</td>
<td>March 1, 2018</td>
<td>-86.67</td>
<td>560.00</td>
<td>1.298347</td>
<td>-10.800</td>
<td>-0.00822</td>
<td>0.001350</td>
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<td>57</td>
<td>March 8, 2018</td>
<td>-86.58</td>
<td>560.00</td>
<td>1.290616</td>
<td>4.394</td>
<td>-0.00821</td>
<td>0.000905</td>
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<td>58</td>
<td>March 15, 2018</td>
<td>-86.51</td>
<td>560.00</td>
<td>1.284150</td>
<td>16.540</td>
<td>-0.00819</td>
<td>0.000462</td>
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<td>59</td>
<td>March 29, 2018</td>
<td>-86.49</td>
<td>560.00</td>
<td>1.280921</td>
<td>21.684</td>
<td>-0.00816</td>
<td>-0.000414</td>
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<td>60</td>
<td>April 12, 2018</td>
<td>-86.50</td>
<td>560.00</td>
<td>1.281771</td>
<td>18.913</td>
<td>-0.00808</td>
<td>-0.001256</td>
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</table>

**Total Delta-**

**Inc (deg)**

-0.04086 0.001047

<table>
<thead>
<tr>
<th>IAM #</th>
<th>Date</th>
<th>Target Yaw Angle (deg)</th>
<th>Burn Duration (sec)</th>
<th>Delta-V (m/sec)</th>
<th>Delta-SMA (m)</th>
<th>Delta-Inc (deg)</th>
<th>Delta-RAAN (deg)</th>
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<tbody>
<tr>
<td>53</td>
<td>February 28, 2018</td>
<td>-82.77</td>
<td>398.00</td>
<td>1.141633</td>
<td>0.046</td>
<td>-0.00852</td>
<td>0.001795</td>
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<td>March 7, 2018</td>
<td>-82.80</td>
<td>398.00</td>
<td>1.135571</td>
<td>0.169</td>
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<td>55</td>
<td>March 14, 2018</td>
<td>-82.83</td>
<td>398.00</td>
<td>1.130478</td>
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<td>-0.00857</td>
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<td>56</td>
<td>March 28, 2018</td>
<td>-82.86</td>
<td>398.00</td>
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<td>-82.89</td>
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<td>1.119324</td>
<td>0.218</td>
<td>-0.00848</td>
<td>-0.000971</td>
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</tbody>
</table>

**Total Delta-**

**Inc (deg)**

-0.04271 0.002945

* Source: Aqua and Aura Lifetime Analysis, October 27, 2017, Spencer Boone and Scott Patano
Aqua Predicted Pre- and Post-2018 IAM MLT

Aqua Mean Local Time

MLT of the Ascending Node (hr)

<table>
<thead>
<tr>
<th>Date</th>
<th>MLT</th>
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<tbody>
<tr>
<td>11/22/2017</td>
<td>13.560</td>
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<tr>
<td>02/20/2018</td>
<td>13.590</td>
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<tr>
<td>05/21/2018</td>
<td>13.600</td>
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<td>08/19/2018</td>
<td>13.580</td>
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<tr>
<td>11/17/2018</td>
<td>13.620</td>
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Constellation Requirement: 13:30:00 ± 15 min
Operational Requirement: 13:35:00 – 13:36:30
Aura Predicted Pre- and Post-2018 IAM MLT

Aura Mean Local Time

MLT of the Ascending Node (hr)

11/22/2017 02/20/2018 05/21/2018 08/19/2018 11/17/2018

2018

Date

2019
Aqua-Aura Lifetime MLT Phasing Based on Planned IAM Strategy

Aqua-Aura Phasing

Constellation Requirement: 8.5 min ±0.25 min
Operational Requirement: 8.61 min – 8.68 min
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Aqua/Aura Spring 2018 Series Planning Summary

• Maintain the Aqua MLT box of 13:35:00 - 13:36:30 and Aqua-Aura MLT relative phasing box of 8.61 - 8.68 minutes in 2019
• The Aqua and Aura Spring 2018 IAM series will consist of five inclination maneuvers for each mission
• Kept changes presented at Spring 2017 MOWG
  – Aqua and Aura burn schedule now 3-1-1, beginning Feb. 28, 2018
  – Aura will burn on Wednesdays
  – Aqua will burn on Thursdays
• Aqua burn duration: 560.0 seconds
• Aura burn duration: 398.0 seconds
• New trending implemented for predicted performance
• Planned Aqua ΔI of -0.04086° is slightly more than Spring 2017 prediction of -0.04083°