International Earth Science Constellation
Mission Operations Working Group
December 6-8, 2017

Aqua/Aura Inclination Adjust Maneuver Series
Spring 2018 Planning

Elena Trenholme, Omitron, Inc.  Spencer Boone, Omitron, Inc.
EOS FDS, esmo-eos-fds@lists.nasa.gov, +1.301.614.5050
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 (ΔI) would be less than presented at 2016 MOWG ( -0.04089° )
    • Burn duration needed to increase to 565.0 seconds from 550.0 seconds
    • Predicted ΔI 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 (ΔSMA) and ΔI 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 ΔI would increase to -0.04120°
  – Burn duration decreased to 560.0 seconds to better match previous value
    • Predicted ΔI: -0.04086°
    • Duty cycles trended from 550.0 second burn duration
      – Burn duration may change to meet advertised ΔI
Aqua Spring 2018 IAM Campaign Planning

- 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>
</tr>
</thead>
</table>
|         |        |         | **February 28**
|         |        |         | Aura IAM#53 | March 1
|         |        |         | Aqua IAM#56 | 2 |
| 4      | 5      | 6       | 7 Aura IAM#54 | 8 Aqua IAM#57 |
| 11     | 12     | 13      | 14 Aura IAM#55 | 15 Aqua IAM#58 |
| 18     | 19     | 20 Equinox | 21 | 22 Aqua Ideal Date |
| 25     | 26     | 27 Aura Ideal Date | 28 Aura IAM#56 | 29 Aqua IAM#59 |
|        |        |         | Aqua IAM#59 | 30 |
|        | April 1| Easter Sunday | 2 | 3 |
| 8      | 9      | 10      | 11 Aura IAM#57 | 12 Aqua IAM#60 |
| 15     | 16     | 17      | 18 | 19 |
|        |        |         | 20 | 21* |

*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>
</tr>
</thead>
<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>
</tr>
<tr>
<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>
</tr>
<tr>
<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>
</tr>
<tr>
<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>
</tr>
<tr>
<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>
</tr>
</tbody>
</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>
</tr>
</thead>
<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>
</tr>
<tr>
<td>54</td>
<td>March 7, 2018</td>
<td>-82.80</td>
<td>398.00</td>
<td>1.135571</td>
<td>0.169</td>
<td>-0.00856</td>
<td>0.001338</td>
</tr>
<tr>
<td>55</td>
<td>March 14, 2018</td>
<td>-82.83</td>
<td>398.00</td>
<td>1.130478</td>
<td>0.049</td>
<td>-0.00857</td>
<td>0.000861</td>
</tr>
<tr>
<td>56</td>
<td>March 28, 2018</td>
<td>-82.86</td>
<td>398.00</td>
<td>1.124416</td>
<td>0.084</td>
<td>-0.00858</td>
<td>-0.000078</td>
</tr>
<tr>
<td>57</td>
<td>April 11, 2018</td>
<td>-82.89</td>
<td>398.00</td>
<td>1.119324</td>
<td>0.218</td>
<td>-0.00848</td>
<td>-0.000971</td>
</tr>
</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 Mean Local Time

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)

Date

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

2018

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
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°