



## 14629 - Astrometry of 2014MU69 for New Horizons encounter

Cycle: 24, Proposal Category: GO

(Availability Mode: SUPPORTED)

### INVESTIGATORS

| <i>Name</i>                            | <i>Institution</i>                                      | <i>E-Mail</i>                  |
|--|---|--------------------------------|
| <b>Dr. Marc W. Buie (PI) (Contact)</b> | <b>Southwest Research Institute</b>                     | <b>buie@boulder.swri.edu</b>   |
| Stephen Gwyn (CoI) (CSA Member)        | Dominion Astrophysical Observatory                      | stephen.gwyn@nrc-cnrc.gc.ca    |
| Dr. Paolo Tanga (CoI) (ESA Member)     | Observatoire de la Cote d'Azur                          | paolo.tanga@oca.eu             |
| Dr. William M Folkner (CoI)            | Jet Propulsion Laboratory                               | william.m.folkner@jpl.nasa.gov |
| Dr. John R. Spencer (CoI)              | Southwest Research Institute                            | spencer@boulder.swri.edu       |
| Dr. J. J. Kavelaars (CoI) (CSA Member) | National Research Council of Canada                     | jj.kavelaars@nrc-cnrc.gc.ca    |
| Dr. Simon Porter (CoI)                 | Southwest Research Institute                            | porter@boulder.swri.edu        |
| Dr. Alex Harrison Parker (CoI)         | Southwest Research Institute                            | alexharrisonparker@gmail.com   |
| Dr. Amanda Marie Zangari (CoI)         | Southwest Research Institute                            | azangari@boulder.swri.edu      |
| Dr. Susan D. Benecchi (CoI)            | Planetary Science Institute                             | susank@psi.edu                 |
| Dr. Anne J. Verbiscer (CoI)            | The University of Virginia                              | verbiscer@virginia.edu         |
| Dr. David Tholen (CoI)                 | University of Hawaii                                    | tholen@ifa.hawaii.edu          |
| Dr. Harold A. Weaver (CoI)             | The Johns Hopkins University Applied Physics Laboratory | hal.weaver@jhuapl.edu          |
| Dr. S. Alan Stern (CoI)                | Southwest Research Institute                            | astern@swri.edu                |

### VISITS

| <i>Visit</i> | <i>Targets used in Visit</i> | <i>Configurations used in Visit</i> | <i>Orbits Used</i> | <i>Last Orbit Planner Run</i> | <i>OP Current with Visit?</i> |
|--------------|------------------------------|-------------------------------------|--------------------|-------------------------------|-------------------------------|
| 01           | (1) 2014MU69                 | WFC3/UVIS                           | 1                  | 27-Apr-2017 21:00:58.0        | yes                           |
| 02           | (1) 2014MU69                 | WFC3/UVIS                           | 1                  | 27-Apr-2017 21:01:00.0        | yes                           |
| 03           | (2) 2014MU69-A               | WFC3/UVIS                           | 1                  | 27-Apr-2017 21:01:01.0        | yes                           |

| <i>Visit</i> | <i>Targets used in Visit</i> | <i>Configurations used in Visit</i> | <i>Orbits Used</i> | <i>Last Orbit Planner Run</i> | <i>OP Current with Visit?</i> |
|--------------|------------------------------|-------------------------------------|--------------------|-------------------------------|-------------------------------|
| 53           | (2) 2014MU69-A               | WFC3/UVIS                           | 1                  | 27-Apr-2017 21:01:02.0        | yes                           |
| 04           | (2) 2014MU69-A               | WFC3/UVIS                           | 1                  | 27-Apr-2017 21:01:02.0        | yes                           |
| 05           | (1) 2014MU69                 | WFC3/UVIS                           | 1                  | 27-Apr-2017 21:01:03.0        | yes                           |
| 06           | (2) 2014MU69-A               | WFC3/UVIS                           | 1                  | 27-Apr-2017 21:01:04.0        | yes                           |

7 Total Orbits Used

### **ABSTRACT**

We propose 12 orbits of time to make high-precision astrometric measurements of the New Horizons extended mission target, 2014MU69. These observations are in direct support of the navigation of New Horizons leading up to its encounter in Jan 2019. These visits represent an optimized plan for improved orbit estimates that will complete as the target becomes directly observable by New Horizons. This astrometry is a key element leading up to a close investigation of a Cold-Classical Kuiper Belt Object, one of the most primitive members of our solar system.

### **OBSERVING DESCRIPTION**

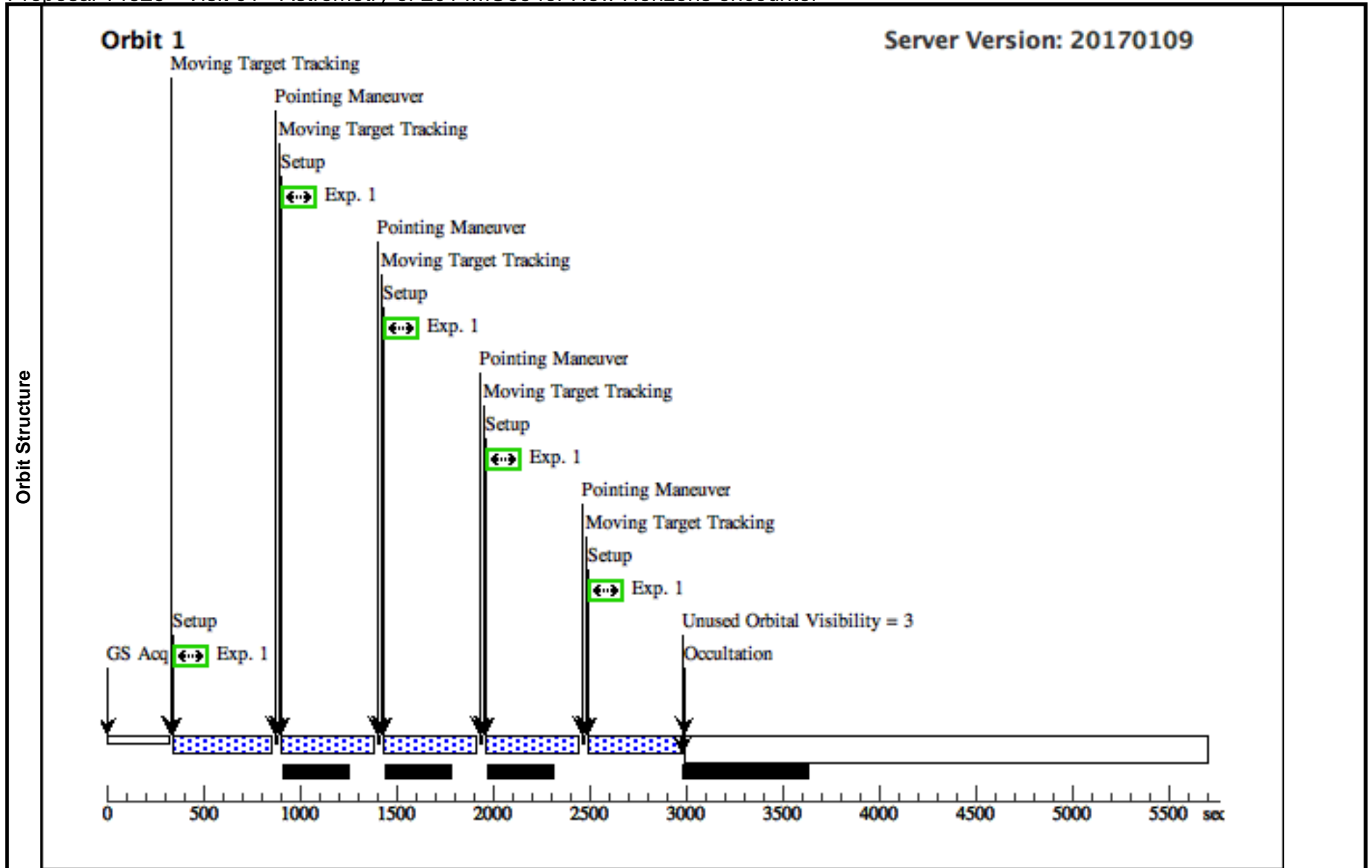
These observations will use the full field of WFC3/UVIS due to its improved broadband PSF and detector sensitivity compared to ACS. This was the HST instrument used to successfully detect 2014MU69 and our other potential KBO targets in our 2014 search campaign. We are using the F350LP filter for its sensitivity and image quality as well as consistency with the prior observations. Our observing strategy is based on the successful strategy developed for our 2014-2016 HST KBO search and followup campaigns. For each HST orbit we will use WFC3 with the F350LP filter to obtain five 370 second exposures. We will track on the known motion of 2014MU69, which results in trailing of stars, but does not prevent their removal to provide robust detections in single orbits as shown. The formal uncertainty of the position is less than 1 pixel for the entire campaign. Thus, the target can easily be placed near the center of WFC3/UVIS2, and very bright stars can be avoided by adjusting the timing of the observations as necessary. Once preliminary observing windows are available we need to examine the background star field for contamination and final scheduling to avoid field stars. We require acquisition of the full WFC3 field for precise astrometric solutions. The visit timing is designed to get broad time coverage for the orbit estimation needed for New Horizons navigation support. The one week period is chosen to provide ample scheduling flexibility and could be shifted by another day or two if needed. The timing of these weeks is controlled by avoiding the

Proposal 14629 (STScI Edit Number: 5, Created: Thursday, April 27, 2017 8:01:05 PM EST) - Overview

time around quadrature when the sky-plane velocity is below 1 arcsec/hour and the need to get the visits spread out in time throughout the annual observing window.

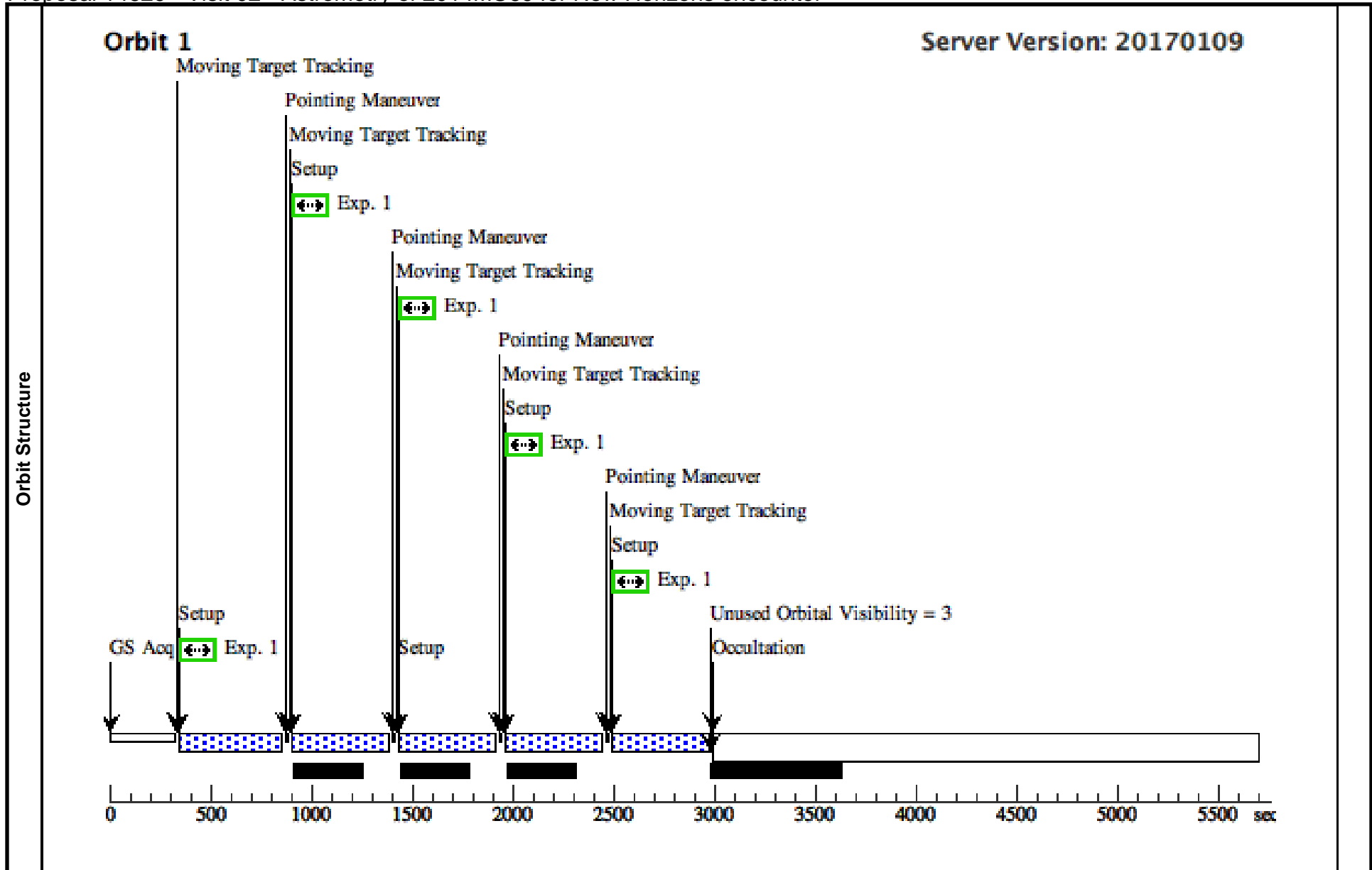
Proposal 14629 - Visit 01 - Astrometry of 2014MU69 for New Horizons encounter

| Visit                | Proposal 14629, Visit 01, completed <span style="float: right;">Fri Apr 28 01:01:05 GMT 2017</span><br>Diagnostic Status: No Diagnostics<br>Scientific Instruments: WFC3/UVIS<br>Special Requirements: SCHED 100%; BETWEEN 25-JUL-2016:00:00:00 AND 01-AUG-2016:00:00:00 |          |  |  |               |              |               |   |  |       |
|----------------------|--|----------|--|--|---------------|--------------|---------------|---|--|-------|
|                      | Patterns   | #        | Primary Pattern  | Secondary Pattern  | Exposures     |              |               |   |  |       |
|                      |  | (1)      | Pattern Type=LINE<br>Purpose=OTHER<br>Number Of Points=5<br>Point Spacing=.030<br>Line Spacing=  | Coordinate Frame=CELESTIAL<br>Pattern Orientation=0<br>Angle Between Sides=<br>Center Pattern=true |               | (1)          |               |   |  |       |
| Solar System Targets | #  | Name     | Level 1  | Level 2  | Level 3       | Window       | Ephem Center  |   |  |       |
|                      | (1)  | 2014MU69 | TYPE=ASTEROID,A=45.8148670278<br>.E=0.035776003052<br>.I=2.453085134109<br>.O=158.938296047929<br>.W=181.783023901528<br>.M=305.281257673465<br>.EQUINOX=J2000,EPOCH=15-MAR-2016:00:00:00,EpochTimeScale=UTC |  |               |              | EARTH         |   |  |       |
| Exposures            | #  | Label    | Target   | Config,Mode,Aperture   | Spectral Els. | Opt. Params. | Special Reqs. | Groups  | Exp. Time (Total)/[Actual Dur.]  | Orbit |
|                      | 1  |          | (1) 2014MU69   | WFC3/UVIS, ACCUM, UVIS2  | F350LP        |              |               | Sequence 1-1 Non-Int in Visit 01<br>Pattern 1, Exps 1-1 in Sequence 1-1 Non-Int in Visit 01 (1) | 367.0 Secs (1835 Secs)<br>[==>(Pattern 1)]<br>[==>(Pattern 2)]<br>[==>(Pattern 3)]<br>[==>(Pattern 4)]<br>[==>(Pattern 5)] | [1]   |



Proposal 14629 - Visit 02 - Astrometry of 2014MU69 for New Horizons encounter

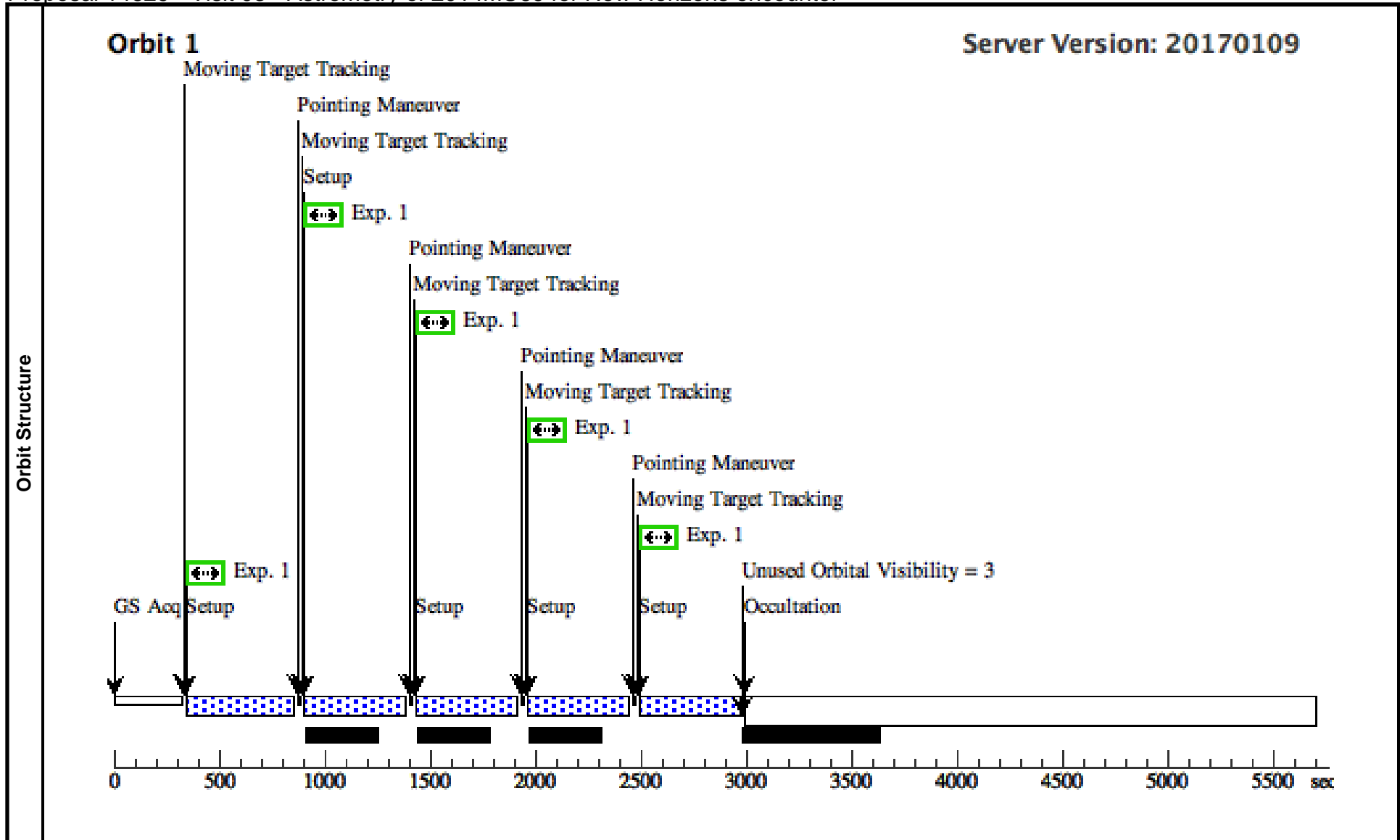
| Visit                | Proposal 14629, Visit 02, completed<br>Diagnostic Status: No Diagnostics<br>Scientific Instruments: WFC3/UVIS<br>Special Requirements: SCHED 100%; BETWEEN 21-OCT-2016:00:00:00 AND 28-OCT-2016:00:00:00 |   |  |  |               |              | Fri Apr 28 01:01:06 GMT 2017 |   |  |       |
|----------------------|--|---|--|--|---------------|--------------|------------------------------|---|--|-------|
| Patterns             | #  | Primary Pattern   | Secondary Pattern  | Exposures  |               |              |                              |   |  |       |
| Solar System Targets | #  | Name  | Level 1  | Level 2  | Level 3       | Window       | Ephem Center                 |   |  |       |
| Exposures            | #  | Label   | Target   | Config,Mode,Aperture   | Spectral Els. | Opt. Params. | Special Reqs.                | Groups  | Exp. Time (Total)/[Actual Dur.]  | Orbit |
|                      | (1)  | Pattern Type=LINE<br>Purpose=OTHER<br>Number Of Points=5<br>Point Spacing=.030<br>Line Spacing= |  | Coordinate Frame=CELESTIAL<br>Pattern Orientation=0<br>Angle Between Sides=<br>Center Pattern=true |               | (1)          |                              |   |  |       |
|                      | (1)  | 2014MU69  | TYPE=ASTEROID,A=45.8148670278<br>.E=0.035776003052<br>.I=2.453085134109<br>.O=158.938296047929<br>.W=181.783023901528<br>.M=305.281257673465<br>.EQUINOX=J2000,EPOCH=15-MAR-2016:00:00:00,EpochTimeScale=UTC |  |               |              |                              | EARTH   |  |       |
|                      | 1  | (1) 2014MU69  | WFC3/UVIS, ACCUM, UVIS2  | F350LP   |               |              |                              | Sequence 1-1 Non-Int in Visit 02<br>Pattern 1, Exps 1-1 in Sequence 1-1 Non-Int in Visit 02 (1) | 367.0 Secs (1835 Secs)<br>[==>(Pattern 1)]<br>[==>(Pattern 2)]<br>[==>(Pattern 3)]<br>[==>(Pattern 4)]<br>[==>(Pattern 5)] | [1]   |



Proposal 14629 - Visit 03 - Astrometry of 2014MU69 for New Horizons encounter

Fri Apr 28 01:01:06 GMT 2017

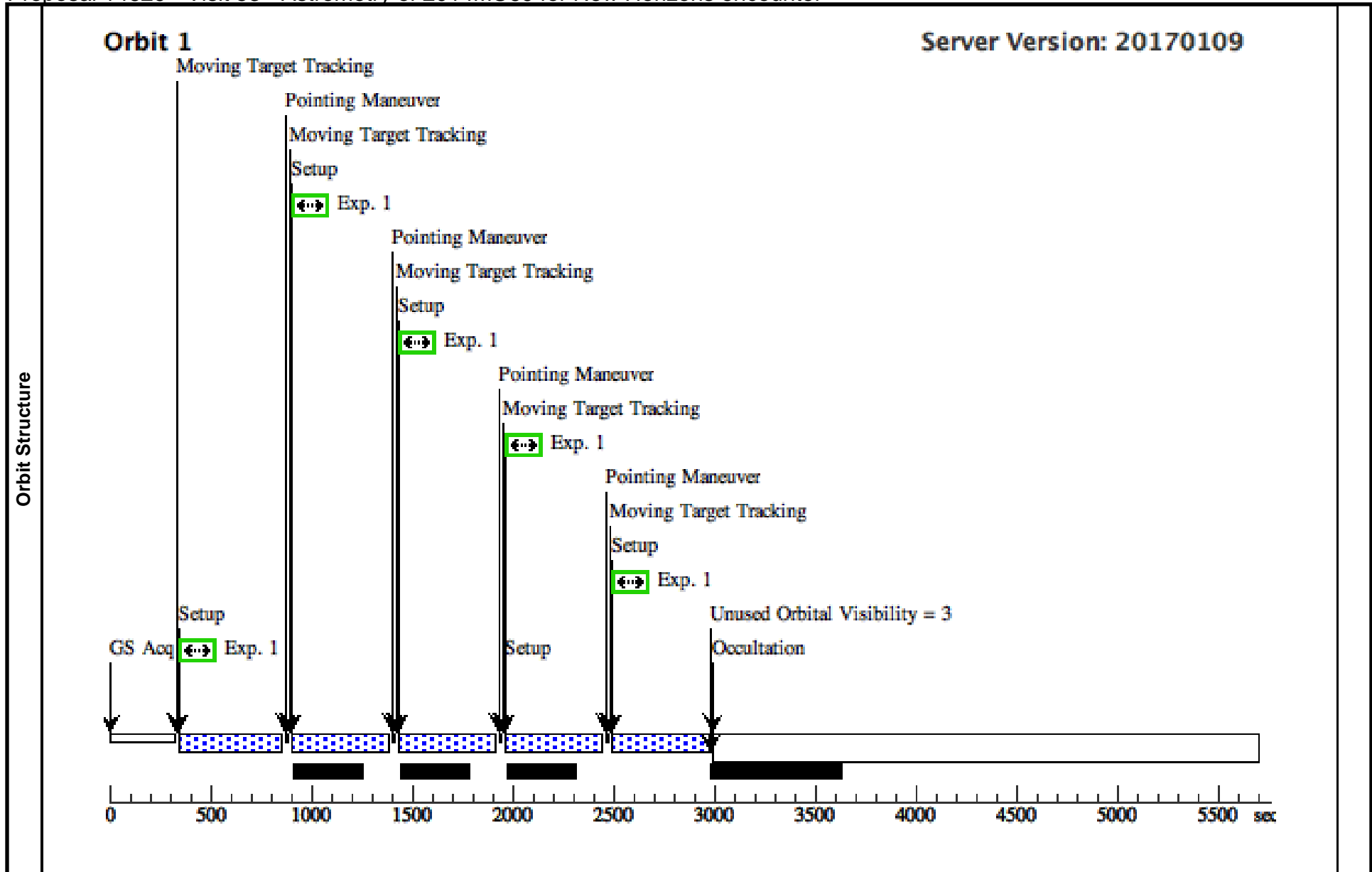
| Visit                | <b>Proposal 14629, Visit 03, failed</b><br><b>Diagnostic Status: No Diagnostics</b><br>Scientific Instruments: WFC3/UVIS<br>Special Requirements: SCHED 100%; BETWEEN 14-MAR-2017:00:00:00 AND 21-MAR-2017:00:00:00 |            |  |  |               |              |               |   |   |       |
|----------------------|---|------------|--|--|---------------|--------------|---------------|---|---|-------|
|                      | Patterns  | #          | Primary Pattern  | Secondary Pattern  | Exposures     |              |               |   |   |       |
|                      |   | (1)        | Pattern Type=LINE<br>Purpose=OTHER<br>Number Of Points=5<br>Point Spacing=.030<br>Line Spacing=  | Coordinate Frame=CELESTIAL<br>Pattern Orientation=0<br>Angle Between Sides=<br>Center Pattern=true |               | (1)          |               |   |   |       |
| Solar System Targets | #   | Name       | Level 1  | Level 2  | Level 3       | Window       | Ephem Center  |   |   |       |
|                      | (2)   | 2014MU69-A | TYPE=ASTEROID,A=44.3524301960<br>11,E=0.037134814649,I=2.453361464<br>855,O=158.928055527100,W=178.195<br>667090867,M=310.080320157793,EQ<br>UINOX=J2000,EPOCH=16-MAR-<br>2017:23:42:51,EpochTimeScale=UTC |  |               |              | EARTH         |   |   |       |
|                      | <i>Comments: Copy of target 1 made Feb-24-2017. This target has updated orbital elements for 2014MU69.</i>  |            |  |  |               |              |               |   |   |       |
| Exposures            | #   | Label      | Target   | Config,Mode,Aperture   | Spectral Els. | Opt. Params. | Special Reqs. | Groups  | Exp. Time (Total)/[Actual Dur.]   | Orbit |
|                      | 1   |            | (2) 2014MU69-A   | WFC3/UVIS, ACCUM, UVIS2  | F350LP        |              |               | Sequence 1-1 Non-Int in Visit 03<br>Pattern 1, Exps 1-1 in Sequence 1-1 Non-Int in Visit 03 (1) | 367.0 Secs (1835 Secs)<br>[=>(Pattern 1)]<br>[=>(Pattern 2)]<br>[=>(Pattern 3)]<br>[=>(Pattern 4)]<br>[=>(Pattern 5)] | [1]   |



Proposal 14629 - Visit 53 - Astrometry of 2014MU69 for New Horizons encounter

Fri Apr 28 01:01:06 GMT 2017

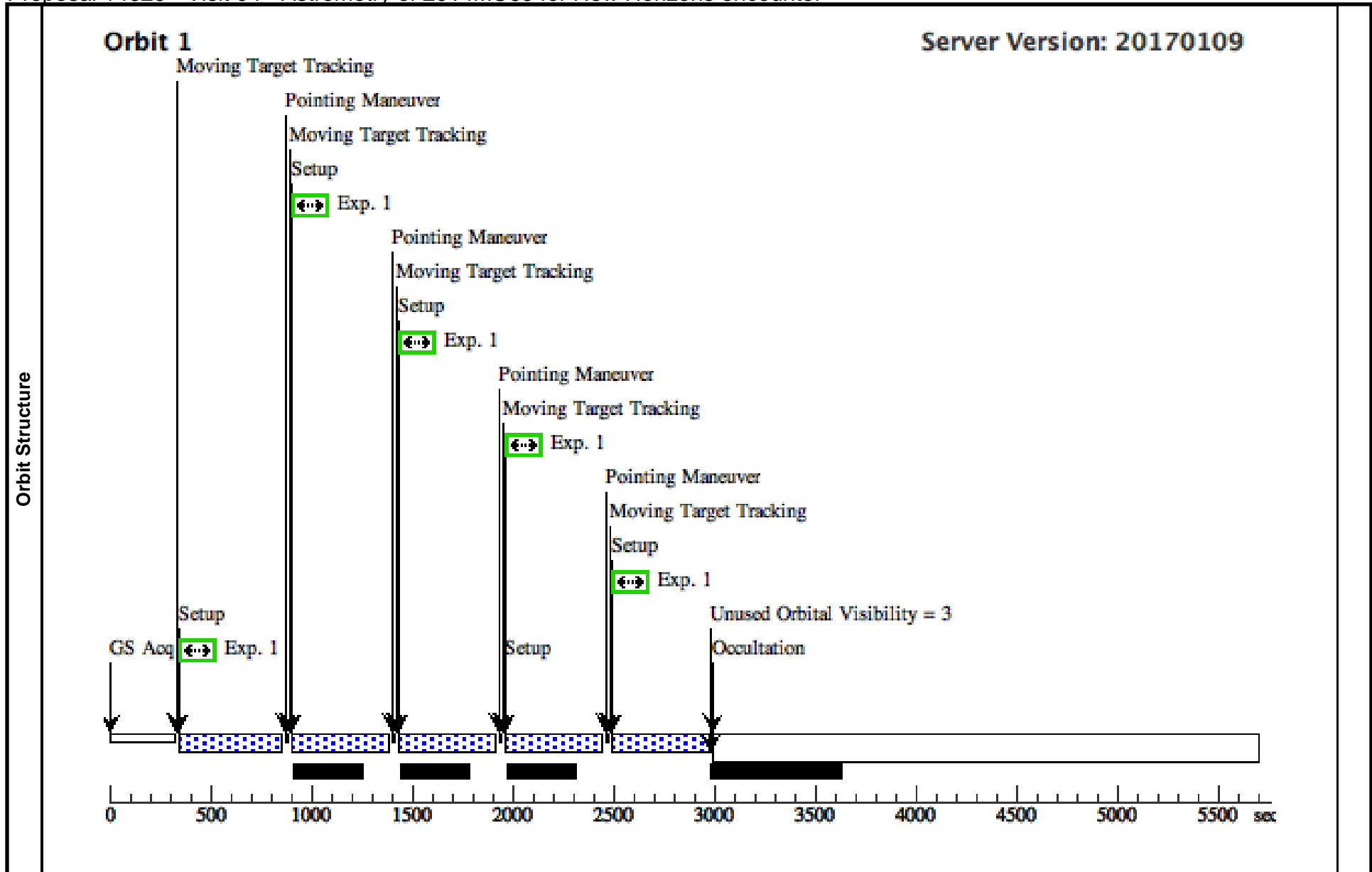
| Visit                | <b>Proposal 14629, Visit 53, scheduled</b><br><b>Diagnostic Status: No Diagnostics</b><br>Scientific Instruments: WFC3/UVIS<br>Special Requirements: SCHED 100%<br><i>Comments: Repeat of visit 3 which was lost due to a SIC&amp;DH lockup on March 16, 2017.</i> |            |  |  |               |              |               |   |   |       |
|----------------------|--|------------|--|--|---------------|--------------|---------------|---|---|-------|
|                      | Patterns   | #          | Primary Pattern  | Secondary Pattern  | Exposures     |              |               |   |   |       |
|                      |  | (1)        | Pattern Type=LINE<br>Purpose=OTHER<br>Number Of Points=5<br>Point Spacing=.030<br>Line Spacing=  | Coordinate Frame=CELESTIAL<br>Pattern Orientation=0<br>Angle Between Sides=<br>Center Pattern=true |               | (1)          |               |   |   |       |
| Solar System Targets | #  | Name       | Level 1  | Level 2  | Level 3       | Window       | Ephem Center  |   |   |       |
|                      | (2)  | 2014MU69-A | TYPE=ASTEROID,A=44.3524301960<br>11,E=0.037134814649,I=2.453361464<br>855,O=158.928055527100,W=178.195<br>667090867,M=310.080320157793,EQ<br>UINOX=J2000,EPOCH=16-MAR-<br>2017:23:42:51,EpochTimeScale=UTC<br><i>Comments: Copy of target 1 made Feb-24-2017. This target has updated orbital elements for 2014MU69.</i> |  |               |              | EARTH         |   |   |       |
| Exposures            | #  | Label      | Target   | Config,Mode,Aperture   | Spectral Els. | Opt. Params. | Special Reqs. | Groups  | Exp. Time (Total)/[Actual Dur.]   | Orbit |
|                      | 1  |            | (2) 2014MU69-A   | WFC3/UVIS, ACCUM, UVIS2  | F350LP        |              |               | Sequence 1-1 Non-Int in Visit 53<br>Pattern 1, Exps 1-1 in Sequence 1-1 Non-Int in Visit 53 (1) | 367.0 Secs (1835 Secs)<br>[=>(Pattern 1)]<br>[=>(Pattern 2)]<br>[=>(Pattern 3)]<br>[=>(Pattern 4)]<br>[=>(Pattern 5)] | [1]   |



Proposal 14629 - Visit 04 - Astrometry of 2014MU69 for New Horizons encounter

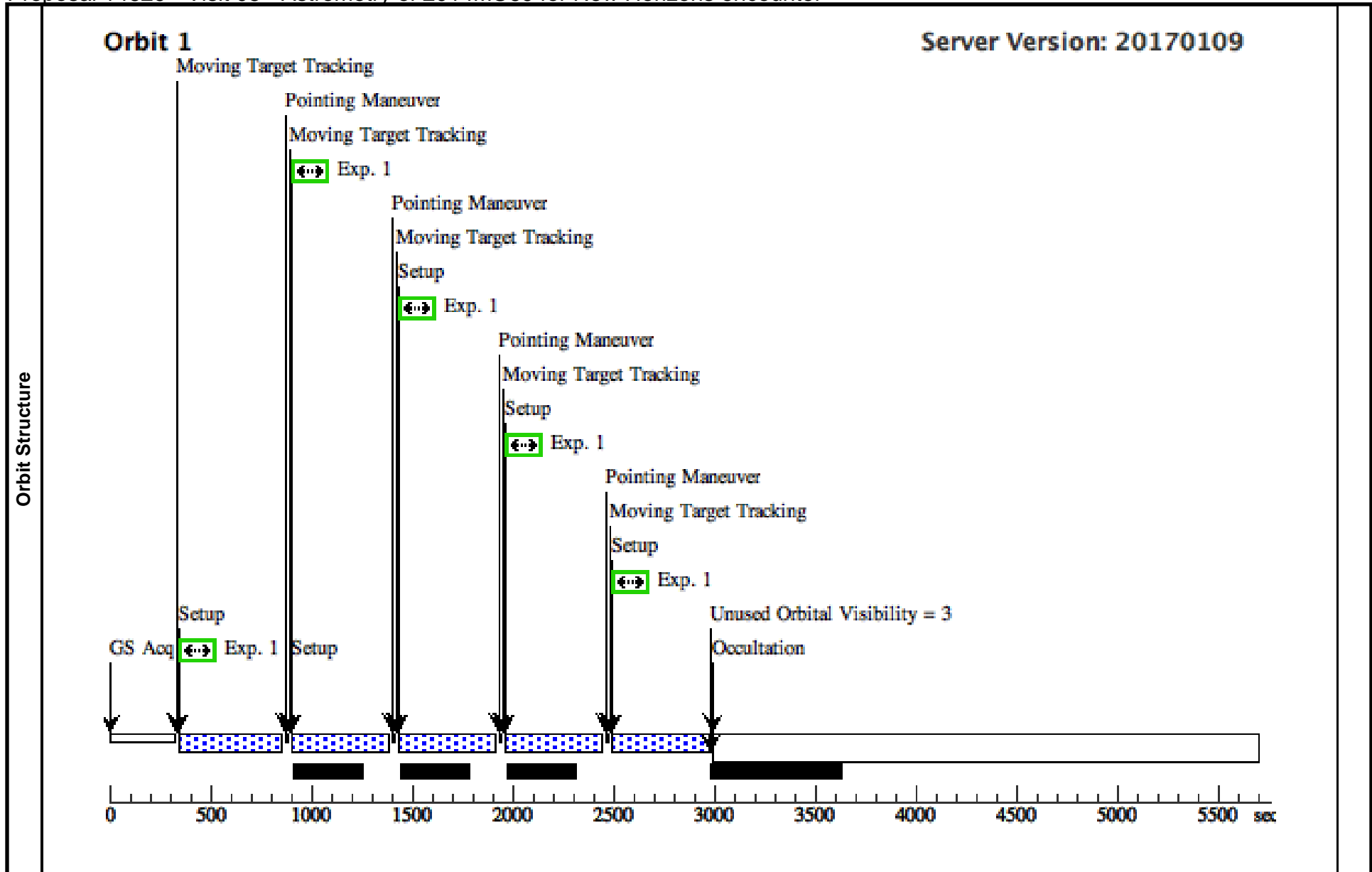
Fri Apr 28 01:01:06 GMT 2017

| Visit                | <b>Proposal 14629, Visit 04, implementation</b><br><b>Diagnostic Status: No Diagnostics</b><br>Scientific Instruments: WFC3/UVIS<br>Special Requirements: SCHED 100%; BETWEEN 25-MAY-2017:16:40:00 AND 25-MAY-2017:17:37:00 |            |  |  |               |              |               |   |   |       |
|----------------------|---|------------|--|--|---------------|--------------|---------------|---|---|-------|
|                      | Patterns  | #          | Primary Pattern  | Secondary Pattern  | Exposures     |              |               |   |   |       |
|                      |   | (1)        | Pattern Type=LINE<br>Purpose=OTHER<br>Number Of Points=5<br>Point Spacing=.030<br>Line Spacing=  | Coordinate Frame=CELESTIAL<br>Pattern Orientation=0<br>Angle Between Sides=<br>Center Pattern=true |               | (1)          |               |   |   |       |
| Solar System Targets | #   | Name       | Level 1  | Level 2  | Level 3       | Window       | Ephem Center  |   |   |       |
|                      | (2)   | 2014MU69-A | TYPE=ASTEROID,A=44.3524301960<br>11,E=0.037134814649,I=2.453361464<br>855,O=158.928055527100,W=178.195<br>667090867,M=310.080320157793,EQ<br>UINOX=J2000,EPOCH=16-MAR-<br>2017:23:42:51,EpochTimeScale=UTC |  |               |              | EARTH         |   |   |       |
|                      | <i>Comments: Copy of target 1 made Feb-24-2017. This target has updated orbital elements for 2014MU69.</i>  |            |  |  |               |              |               |   |   |       |
| Exposures            | #   | Label      | Target   | Config,Mode,Aperture   | Spectral Els. | Opt. Params. | Special Reqs. | Groups  | Exp. Time (Total)/[Actual Dur.]   | Orbit |
|                      | 1   |            | (2) 2014MU69-A   | WFC3/UVIS, ACCUM, UVIS2  | F350LP        |              |               | Sequence 1-1 Non-Int in Visit 04<br>Pattern 1, Exps 1-1 in Sequence 1-1 Non-Int in Visit 04 (1) | 367.0 Secs (1835 Secs)<br>[=>(Pattern 1)]<br>[=>(Pattern 2)]<br>[=>(Pattern 3)]<br>[=>(Pattern 4)]<br>[=>(Pattern 5)] | [1]   |



Proposal 14629 - Visit 05 - Astrometry of 2014MU69 for New Horizons encounter

| Visit                | Proposal 14629, Visit 05, completed <span style="float: right;">Fri Apr 28 01:01:06 GMT 2017</span><br>Diagnostic Status: No Diagnostics<br>Scientific Instruments: WFC3/UVIS<br>Special Requirements: SCHED 100%; AFTER 02 BY 3 D TO 5 D; BETWEEN 24-OCT-2016:00:00:00 AND 31-OCT-2016:00:00:00 |   |  |                         |               |              |               |   |  |       |
|----------------------|--|---|--|-------------------------|---------------|--------------|---------------|---|--|-------|
|                      | Patterns   | #   | Primary Pattern  | Secondary Pattern       | Exposures     |              |               |   |  |       |
|                      | (1)  | Pattern Type=LINE<br>Purpose=OTHER<br>Number Of Points=5<br>Point Spacing=.030<br>Line Spacing= | Coordinate Frame=CELESTIAL<br>Pattern Orientation=0<br>Angle Between Sides=<br>Center Pattern=true   |                         | (1)           |              |               |   |  |       |
| Solar System Targets | #  | Name  | Level 1  | Level 2                 | Level 3       | Window       | Ephem Center  |   |  |       |
|                      | (1)  | 2014MU69  | TYPE=ASTEROID,A=45.8148670278<br>.E=0.035776003052<br>.I=2.453085134109<br>.O=158.938296047929<br>.W=181.783023901528<br>.M=305.281257673465<br>.EQUINOX=J2000,EPOCH=15-MAR-2016:00:00:00,EpochTimeScale=UTC |                         |               |              | EARTH         |   |  |       |
| Exposures            | #  | Label   | Target   | Config,Mode,Aperture    | Spectral Els. | Opt. Params. | Special Reqs. | Groups  | Exp. Time (Total)/[Actual Dur.]  | Orbit |
|                      | 1  |   | (1) 2014MU69   | WFC3/UVIS, ACCUM, UVIS2 | F350LP        |              |               | Sequence 1-1 Non-Int in Visit 05<br>Pattern 1, Exps 1-1 in Sequence 1-1 Non-Int in Visit 05 (1) | 367.0 Secs (1835 Secs)<br>[==>(Pattern 1)]<br>[==>(Pattern 2)]<br>[==>(Pattern 3)]<br>[==>(Pattern 4)]<br>[==>(Pattern 5)] | [1]   |



Proposal 14629 - Visit 06 - Astrometry of 2014MU69 for New Horizons encounter

Fri Apr 28 01:01:06 GMT 2017

| Visit  | <b>Proposal 14629, Visit 06, implementation</b><br><b>Diagnostic Status: No Diagnostics</b><br>Scientific Instruments: WFC3/UVIS<br>Special Requirements: SCHED 100%; BETWEEN 19-AUG-2017:00:00:00 AND 26-AUG-2017:00:00:00 |            |  |  |               |              |               |   |   |       |
|--|---|------------|--|--|---------------|--------------|---------------|---|---|-------|
|  | Patterns  | #          | Primary Pattern  | Secondary Pattern  | Exposures     |              |               |   |   |       |
|  |   | (1)        | Pattern Type=LINE<br>Purpose=OTHER<br>Number Of Points=5<br>Point Spacing=.030<br>Line Spacing=  | Coordinate Frame=CELESTIAL<br>Pattern Orientation=0<br>Angle Between Sides=<br>Center Pattern=true |               | (1)          |               |   |   |       |
| Solar System Targets   | #   | Name       | Level 1  | Level 2  | Level 3       | Window       | Ephem Center  |   |   |       |
|  | (2)   | 2014MU69-A | TYPE=ASTEROID,A=44.3524301960<br>11,E=0.037134814649,I=2.453361464<br>855,O=158.928055527100,W=178.195<br>667090867,M=310.080320157793,EQ<br>UINOX=J2000,EPOCH=16-MAR-<br>2017:23:42:51,EpochTimeScale=UTC |  |               |              | EARTH         |   |   |       |
| <i>Comments: Copy of target 1 made Feb-24-2017. This target has updated orbital elements for 2014MU69.</i> |   |            |  |  |               |              |               |   |   |       |
| Exposures  | #   | Label      | Target   | Config,Mode,Aperture   | Spectral Els. | Opt. Params. | Special Reqs. | Groups  | Exp. Time (Total)/[Actual Dur.]   | Orbit |
|  | 1   |            | (2) 2014MU69-A   | WFC3/UVIS, ACCUM, UVIS2  | F350LP        |              |               | Sequence 1-1 Non-Int in Visit 06<br>Pattern 1, Exps 1-1 in Sequence 1-1 Non-Int in Visit 06 (1) | 367.0 Secs (1835 Secs)<br>[=>(Pattern 1)]<br>[=>(Pattern 2)]<br>[=>(Pattern 3)]<br>[=>(Pattern 4)]<br>[=>(Pattern 5)] | [1]   |

