Mobile and Multiple Station Deployments for Asteroidal Occultations

First, read about how to observe asteroidal occultations in general. Many resources are already at the main IOTA Web site, https://occultations.org/, especially the Observing tab, but also the Occultations, Citizen Science, and Publications (especially the IOTA Observer's Handbook) tabs. Shorter than the Handbook, and more up-to-date, is George Viscome's Primer at https://occultations.org/documents/OccultationObservingPrimer.pdf - it is a good starting point for everything below.

A key to the success of the Near-Earth Asteroid (NEA) occultations observed so far has been the ability of IOTA observers to deploy multiple stationary telescopes with recording systems that can record video at pre-set times and that are pre-pointed to the altitude and azimuth of the occultation using stars [1, 2, 4]. In some cases, special compact telescopes have been constructed, to facilitate transport and, in some cases, to allow pre-pointing on nights before the night of the event, providing much more time for this task [3, 5]. The story of IOTA's successes with NEA occultations was presented at the recent Planetary Defense conference 2021 [6]. Scotty Degenhardt described how to produce pre-point charts using Guide 8 [7]. The update information and .zip files given at the top of Scotty's Web page are not needed now; the functionalities are all now standard features in the current version of Project Pluto's Guide9.1 package. Ernie Iverson updated Scotty's write-up and expanded it some, in an unfinished Word file that I attach [8]. The largest remote-station telescopes used so far are Hyperstar 14-in. Celestrons by Roger Venable; he has built special low alt-az mounts for them so he doesn't have to hoist them up on high tripods. For the 2017 Arrokoth occultations, John Broughton and I suggested constructing larger versions of John's 10-in. "suitcase" telescopes; we felt that a 20-in. version could be made whose components would still fit in a standard (but ruggedized and well-padded) airline suitcase, as the 10-in. versions do easily. But due to some setbacks at the time, John was not able to build a proto-type, and instead, SwRI bought and used, 16-in. Skywatcher GoTO Dobsonians (22 of them), each operated by two people. SwRI developed a "plankton" of instructions for using the 16-in. Skywatchers and the QHY 174M GPS cameras for observing occultations; the latest version [9] that I have is attached. We use many of the same procedures with our 16-in. Skywatchers. SwRI has a good set of instructional YouTube videos, but I can't find them. One about using Sharpcap with a QHY 174M GPS camera [10] is referenced in a recently-distributed paper on calibration of that camera. About a year and a half ago, we pre-pointed our 16-in. Skywatcher in our enclosed back yard in Arizona, and successfully ran it as a remote station while we went mobile with a 10-in. suitcase scope, to make another (attended site mobile) observation in the mountains about 20 miles to the northeast. Other larger telescopes have been used for mobile observations, including a 20-in. scope used by Kai Getrost for Apophis occultations [6]; the IOTA-ES "M2" 20-in. scope used by Mike Kretlow and others, even travelling with it to Namibia [11]; and a 1-meter portable scope used by astronomers from Observatoire de la Côte d'Azur [12] in France.

Automating Stations: There are some developments that can, or might, make mobile or multiple-station deployments easier. One of these is plate-solving software like Astrometrica and Astrototilla that can ingest a CCD or video frame of a star field, and use a database of stellar data, to ID a field, giving the coordinates of the center, the size of the FOV and its orientation. We've got that to work sometimes, especially at home with our QHY camera and 16-in. Skywatcher, but not consistently in the field with our smaller telescopes. In our experience, we've fund that the plate-solving process can easily be confused by hot pixels and sometimes gives wrong solutions. Ideally, the software should give the J2000 RA & Dec, and the altitude and azimuth, of the field center. From that, it could figure out how to get from there to the target, or to the pre-point line. UVA's Mike Skrutskie has got this to work with what he calls a "Mikey Mini", see his email message [13]. In 2020, Steve Conard's intern student Alex Knox implemented a completely automatic mobile deployable Go-To and occultation recording system with a 5-inch SCT [14]. Astronomers at Yale have suggested setting up a network of 2000 automated 16-in. telescopes on cell phone towers across the USA [15]. The paper primarily discusses the expected flux of observable Trojan occultations, and how they would constrain Planet 9's orbit, so it includes a lot of mathematics and dynamics. I was disappointed that it didn't mention IOTA, or the existing archive of asteroidal occultation observations, at all; it did give a reference to Buie et al's 2015 paper on the 2013 October occultation by Patroclus and Menoetius. SwRI has their own ideas about automated stations, not as grandiose as the Yale plane, but they would use sites near cell phone towers, to have access to power and wifi for control and data handling. Unistellar's eVscope is a nice compact easily-transported but relatively expensive system for automatically finding asteroidal occultation targets and recording them; some ways to improve the timing with eVscopes using GPS 1PPS flashes are mentioned in an exchange of messages with Henry Throop, an eVscope occultation observer [16]. Aart Olsen's Arduino flash timer mentioned in the eVscope timing document could be used with other CCD cameras. Bill Hanna, in Montana, USA, with help from local astronomers, has set up an occultation observatory in Yass, Australia [17]. He also developed some ideas for an automated pointing system with an 80mm scope [18] that had a different approach, but was a predecessor of the system that Alex Knox implemented [14]. By spending enough money, some interesting things have been, and can be, accomplished with remote automated stations; IOTA's work shows that it is practical and even fun, but currently-used techniques are rather labor-intensive. The ideas mentioned in this last section shows there's great promise for innovation to make mobile and remote-station deployments more practical for more astronomers, amateur and professional.

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References

1. Dunham, D., Dunham, J., and Broughton, J., "Promise and Problems of Deploying Multiple Stations for Asteroidal and Outer Solar System Occultations", Poster, European Symposium on Occultation Projects, Paris, FR, 2019 August. https://lesia.obspm.fr/lucky-star/esop38/doc/J1-D.Dunham.pdf .
2. Degenhardt, S., "Multi-Station Occultation Observing with Galileo Sized Optical Systems", in *Small Telescopes and Astronomical Research*, Collins Foundation Press, Santa Margarita, Calif., 2009, http://scottysmightymini.com/PR/Effects_miniature_optics_occultations.html Accessed 2021 July.
3. Dunham, D., Dunham, J., and Broughton, J., "Versatile Paver Mounts – Enabling Previous-Night Pre-Pointing and More – 2016 Update", IOTA Meeting, Stillwater, OK, 2016 July 30, https://occultations.org/community/meetingsconferences/na/2016-annual-meeting/2016-annual-meeting-presentations/Sat07_Dunham_pavermounts.ppt

4. Dunham, D. W., “Observing Asteroidal Occultations from Multiple Stations”, IOTA Meeting, College Park, MD, 2014 July 13, https://occultations.org/community/meetingsconferences/na/na2014/2014-presentations-page-2/MultiStation Deployments.ppt.
5. Broughton, J., “Ultra-Portable Telescopes for Occultation Expeditions”, presented at the 14th Trans-Tasman Symposium on Occultations, 2020 April 13, http://www.occultations.org.nz/meetings/TTSO14/UltraPortableTelescopes.mp4, accessed 2021 May 14.
6. Dunham, D. et al., “Accurate NEO Orbits from Occultation Observations”, 7th Planetary Defense Conference, online, https://az659834.vo.msecnd.net/eventsairwesteuprod/production-atpi-public/ec5f493be5634eb286753962eda1488c, 2021 April 26-30, accessed 2021 July 9.
7. Degenhardt, S., “How to Make Guide 8 Prepoint Charts for Asteroid or Lunar Occultations”, http://scottysmightymini.com/tools/How_to_make_Guide8_prepoints.htm, 2008, accessed 2021 July 9.
8. Iverson, E., “How to Make Pre-point Charts using Guide 8/9”, 2016, with a (very) few additions by D. Dunham, unpublished, but in the attached file Guide9tutorialEI1.docx.
9. Buie, M., “Event Night Steps”, 2018, unpublished, but in the attached PlanktonEventNight2018July31.docx.
10. Buie, M. “RECON 2.0 Video Guides | Using SharpCap to Record with QHY Camera.” YouTube. YouTube, September 3, 2020. https://www.youtube.com/watch?v=tNaToOa-Kh0&t=3s.
11. Kretlow, M., “Report about the 2017 Apr 09 Chariklo Occultation Observation”, *Journal for Occultation Astronomy*, issue 2017_2, pp. 13-14, 2017, available https://www.iota-es.de/JOA/JOA2017_2.pdf, accessed 2021 July 9.
12. Tanga, P., et al., “Stellar occultations by NEAs, challenges and opportunities”, 7th Planetary Defense Conference, online, https://az659834.vo.msecnd.net/eventsairwesteuprod/production-atpi-public/e02c4370f7fe4e12ab0688f531dc571c, 2021 April 26-30, accessed 2021 July 9.
13. Skrutskie, M., email message about Mikey Mini, 2020 July 10, in the attached MikeyMini2020July.docx
14. Knox, A., “A Fully Automated Remote Station System”, at the online 2020 IOTA meeting, 4th presentation at https://occultations.org/community/meetingsconferences/na/2020-iota-annual-meeting/presentations-at-the-2020-annual-meeting/, 2020 July 25, accessed 2021 July 11. It is worth listening to the presentation by clicking on the YouTube link.
15. Rice, M. and Laughlin, G., “The Case for a Large-scale Occultation Network”, *Astronomical Journal,* Vol. 158, #19 (18 pages), 2019, available at https://iopscience.iop.org/article/10.3847/1538-3881/ab21df, accessed 2021 July 11.
16. Dunham, D. and Throop, H., exchange of messages about timing and recording occultations with eVscopes, 2021 July, in the attached eVscopeOccultationTiming.docx
17. Hanna, W., “Setting up a Remotely-Controlled Observatory”, presented at the 13th Trans-Tasman Symposium on Occultations, New Plymouth, New Zealand, 2019 May. I remember the presentation, but I don’t have a copy of it to distribute; Bill should be able to provide it.
18. Hanna, W., “Autonomous Mobile Observing Stations”, 2016, available at the IOTA meeting presentations page at https://occultations.org/community/meetingsconferences/na/2016-annual-meeting/2016-annual-meeting-presentations/ click on the presentation name that’s 6th from the bottom of the Friday presentations to download the PowerPoint file.

David Dunham, Version 2, 2021 July 12