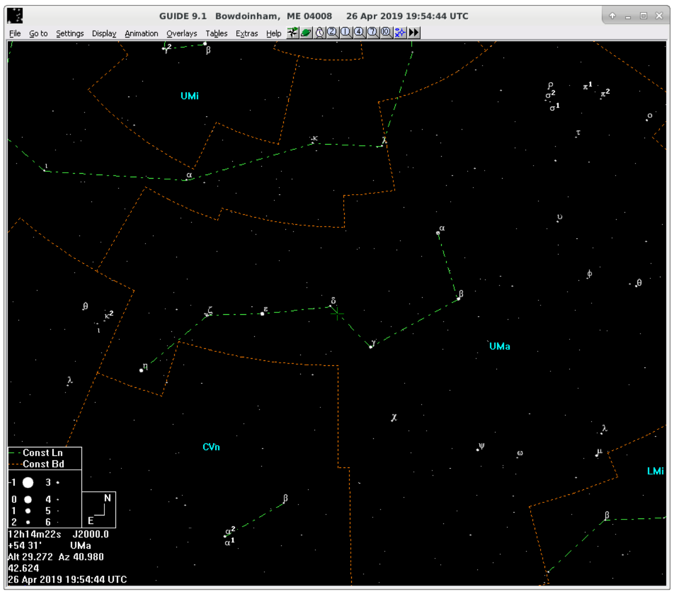
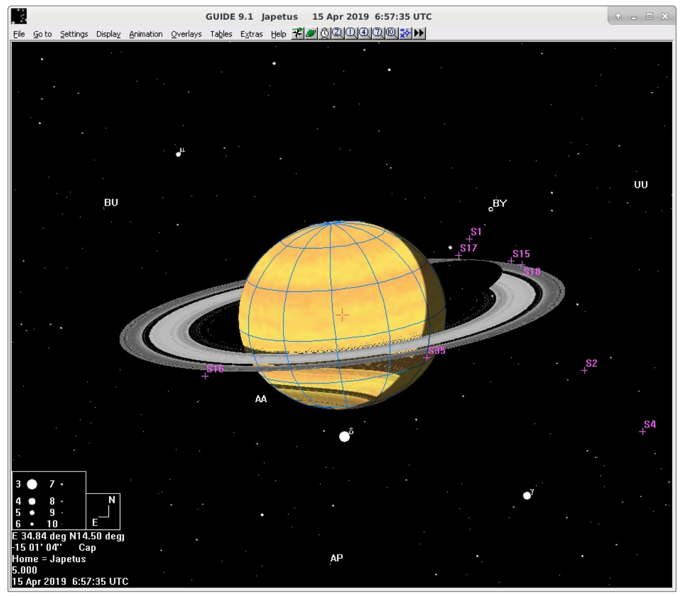
Find_Orb : software to determine orbits from observations

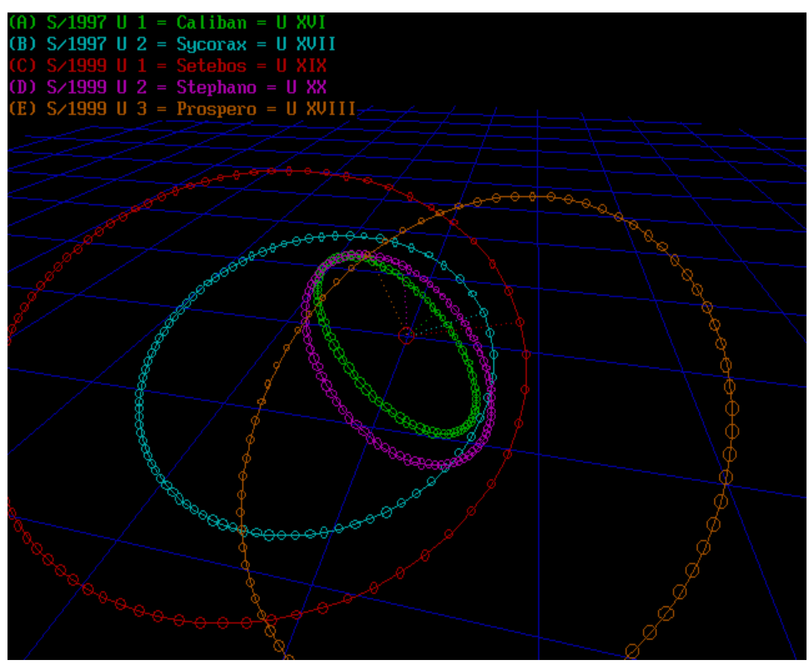
<u>Origin story :</u>

- First version circa 1997, to read optical observation data and find an orbit
- Based on code written for desktop planetarium/star charting; this provided “basic astronomical functions”



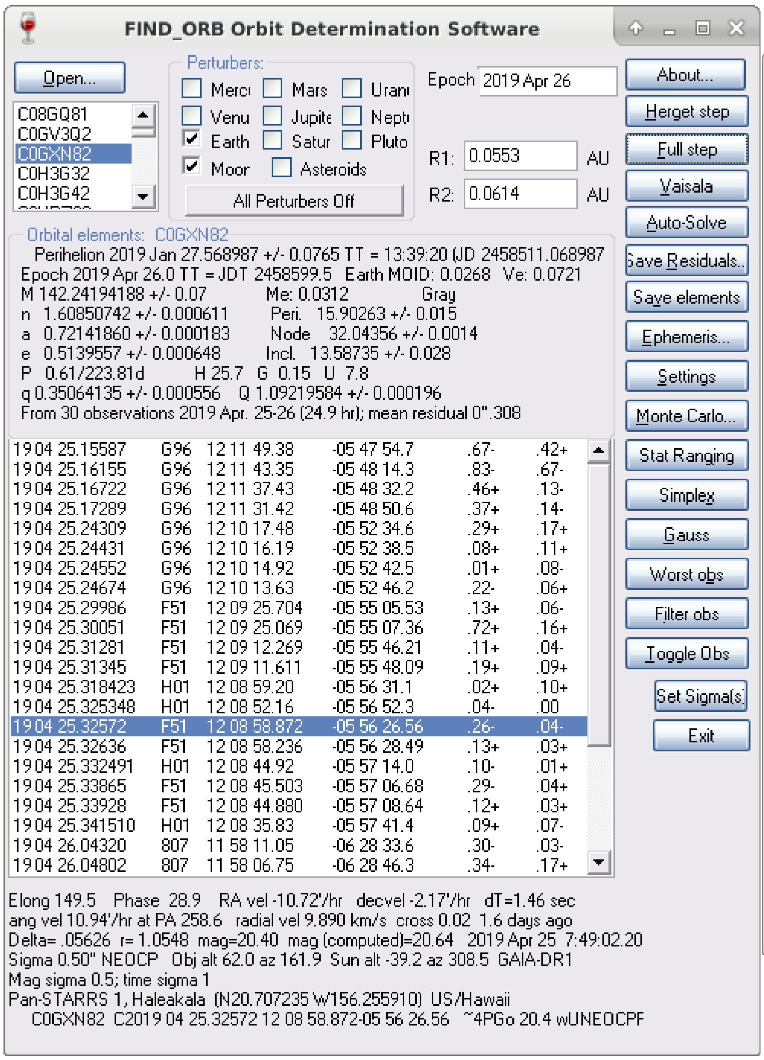


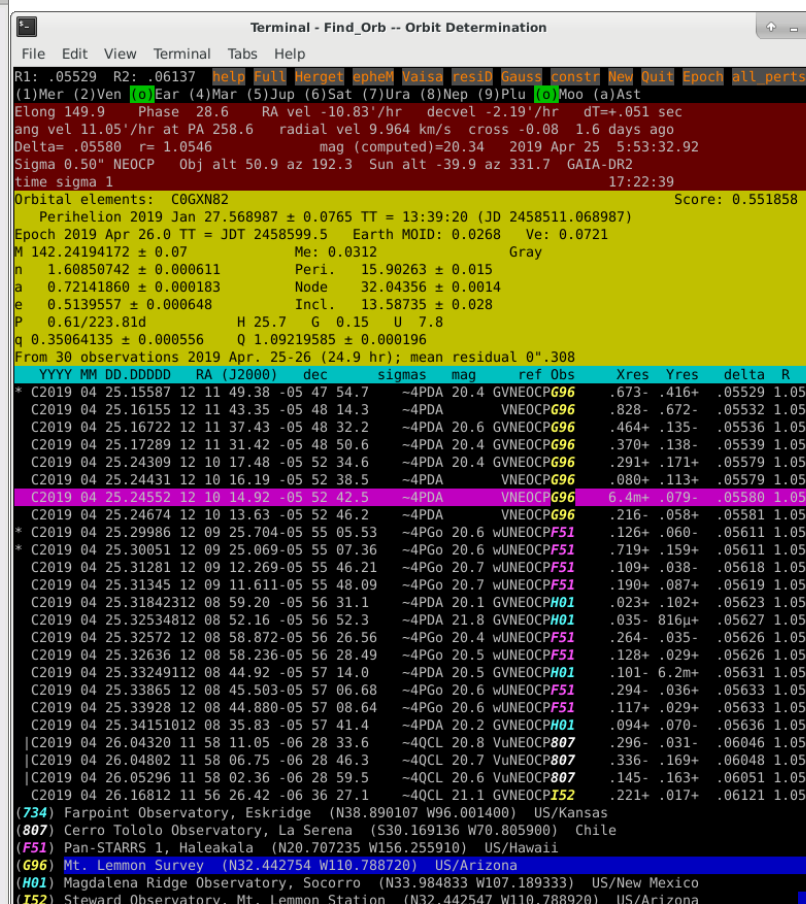
- Intended for educational purposes, both of its users and its developer
- Interactive only, to force you to think about what you’re doing
- Originally for asteroids and comets; quickly added irregular gas giant satellites, artificial satellites
- At the time, filled a near-void (publicly available software to determine orbits was rare to nonexistent)

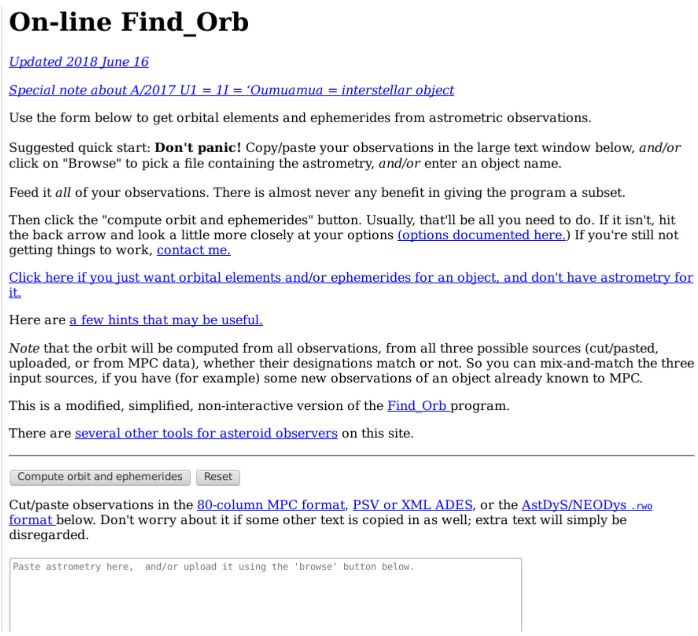


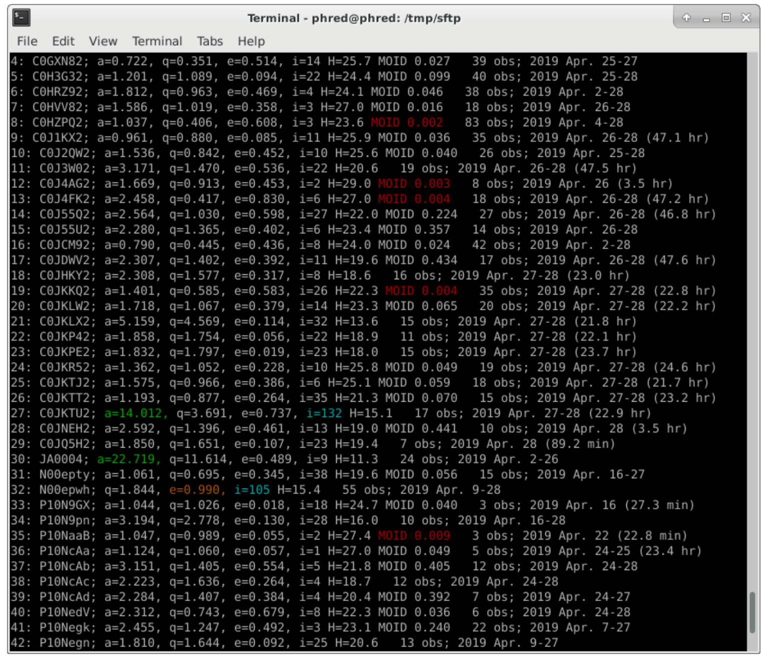
Evolution :

- Still some educational use, but increasing use by observers
- Switch to emphasis on being easy to use, possibly by very tired and busy observers; orbits should be (and increasingly are) found automatically
- Development proceeds on Windows GUI and Linux text-based versions…





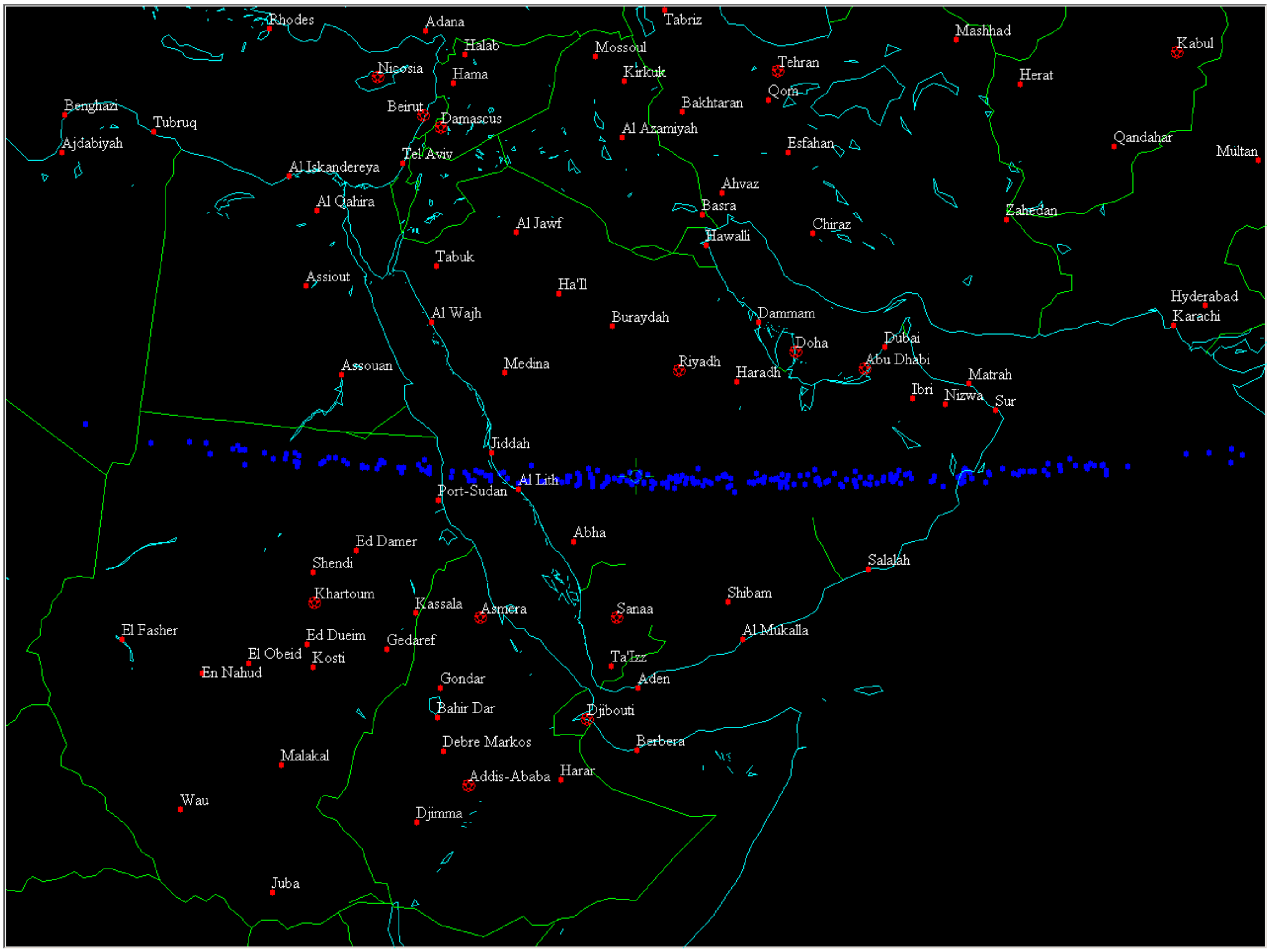




and an on-line version (upload astrometry, get an orbit) and a non-interactive batch version. The software is used both to analyze astrometric data and to figure out where and when to look for objects (observational planning).

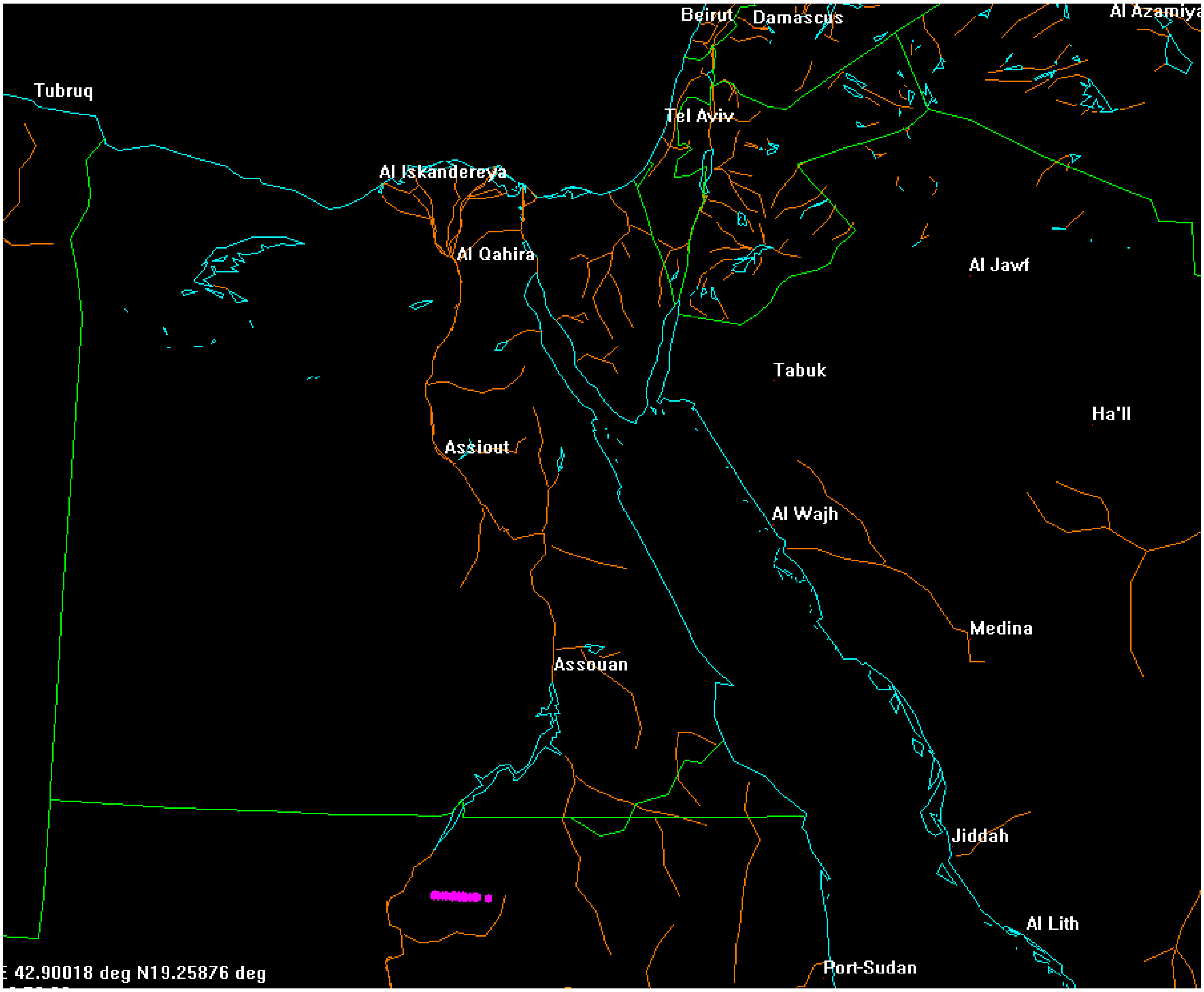
First small impactor:

• 2008 TC3 is found by the Catalina Sky Survey on 2008 October 6, and enters the atmosphere over northern Sudan, 2008 October 7. Impact is predicted independently by MPC, JPL, me, and a Find_Orb user in the UK (Peter Birtwhistle). Orbit determination and impact prediction capabilities are available to world + dog.



• Find_Orb was not entirely ready for this event. After 2008 TC3 (sadly, not before), the ability to create plots of the possible impact area was added (such as the above, based on the initial data we had.)

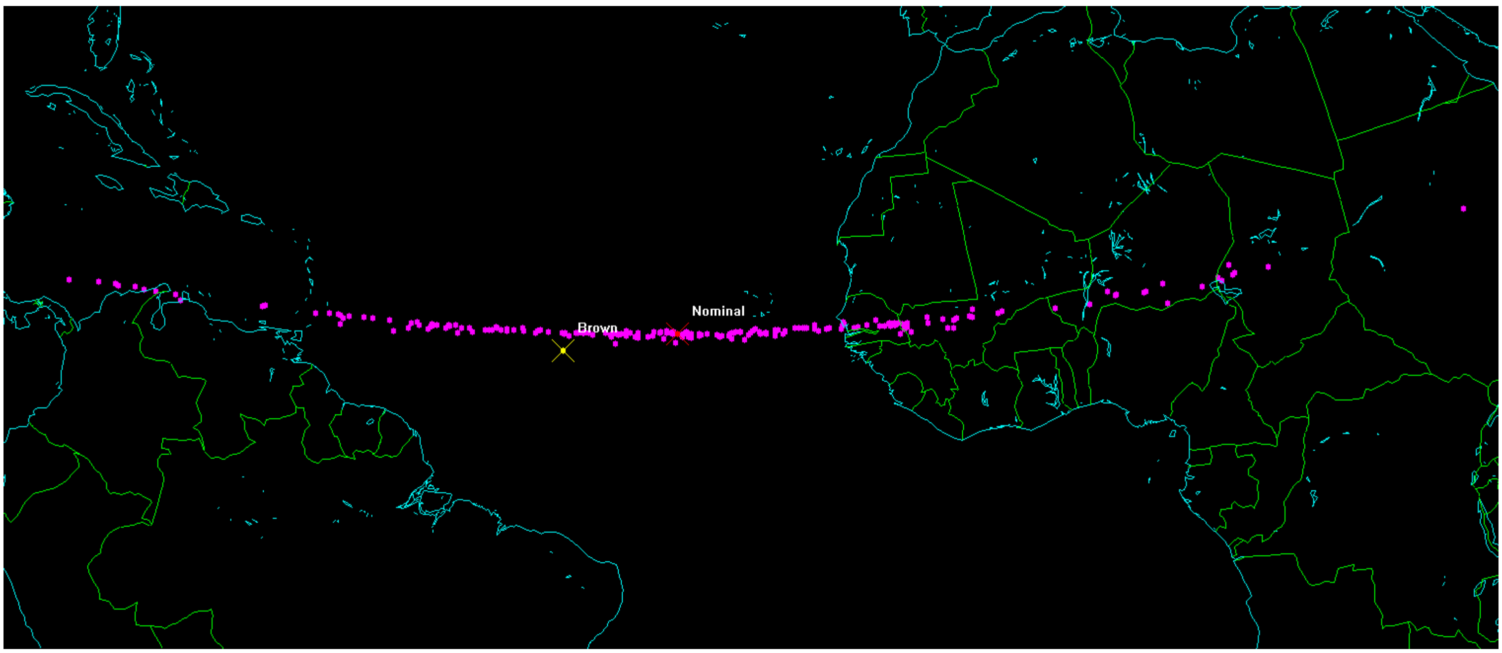
Fortunately, we did get further data from telescopes in Australia, and the impact region decreased a lot…



...and eventually, with further data, was a mere kilometer across.

2014 AA: The second impactor

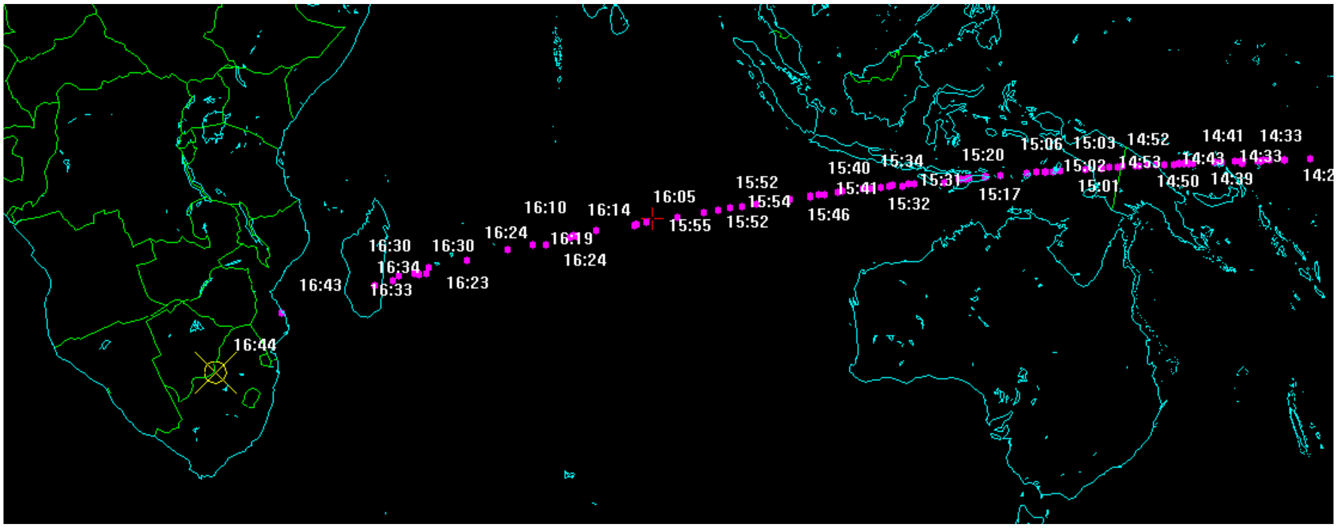
• 2014 Jan 1 : this object was (also) found by CSS, but wasn't recognized as an impactor until approximately the time it probably hit us, so we didn't get much astrometric data
• Just based on the data we did get, it could have hit anywhere from Africa to Central America. Infrasound detection by the CTBT sensors narrowed it down to the point indicated with a yellow X.
• Object was overlooked partly due to data reporting limitations (no uncertainties given for the observations). This problem remains only partially fixed five years later.



The third impactor : 2018 LA

• 2018 Jun 3: JPL's Scout system figured this one out first, almost immediately

• Catalina re-measured their observations, resulting in my generating the following map of possible impact locations :



• Object was observed entering atmosphere over Botswana (yellow circle-X)

• ATLAS submitted observations shortly after impact

• Getting follow-up data for such objects from ATLAS on a regular basis would be a game-changer