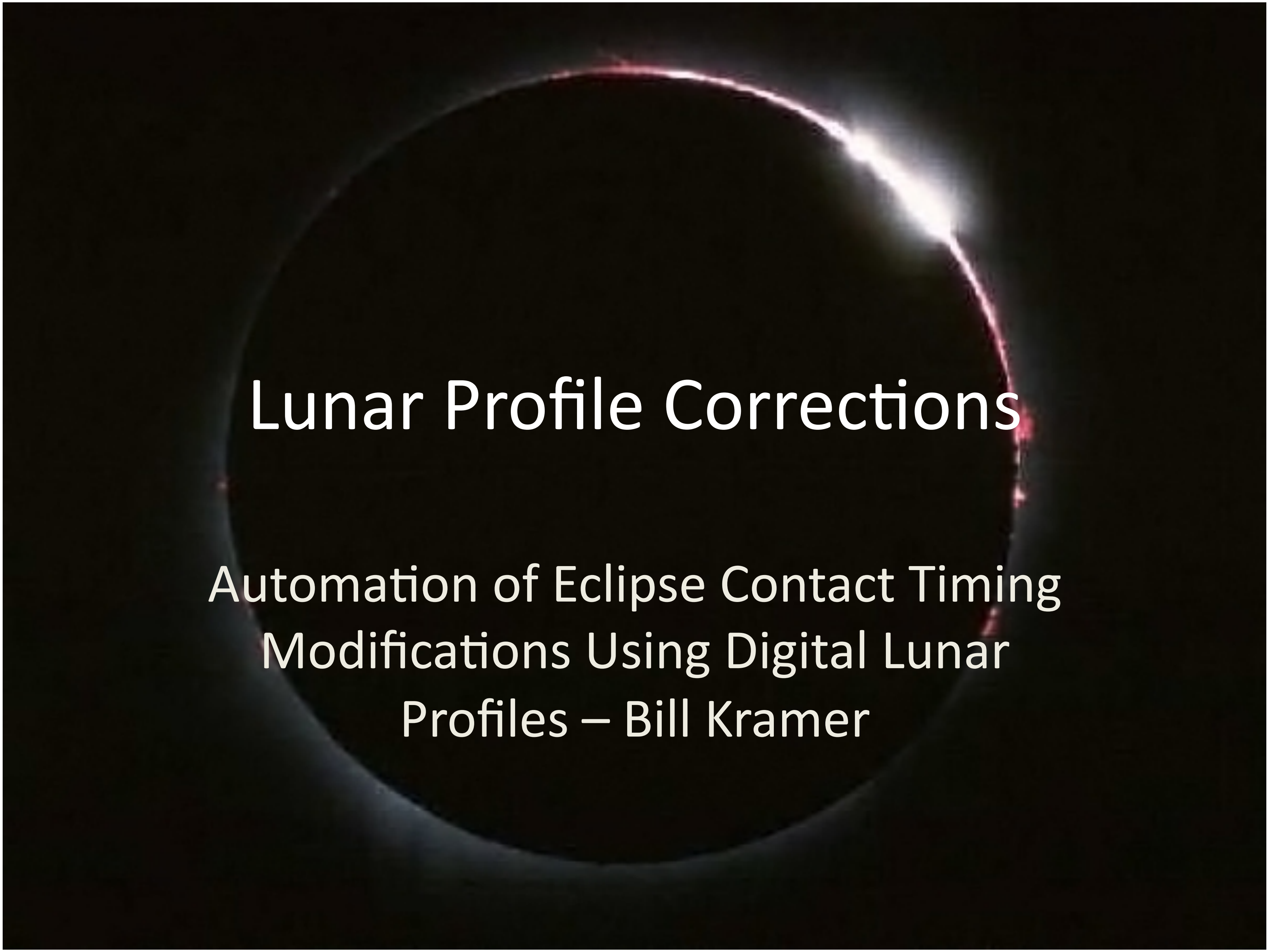


Lunar Profile Corrections

Automation of Eclipse Contact Timing Modifications Using Digital Lunar Profiles – Bill Kramer


Sorry, seems I missed a decimal or slipped a sign.

- Eclipse Prediction requires precise knowledge of the Sun and Moon positions in the future.
  - These positions are known quite well these days.

•Developed in the 1700s, the calculations make use of several approximations and simplifications.

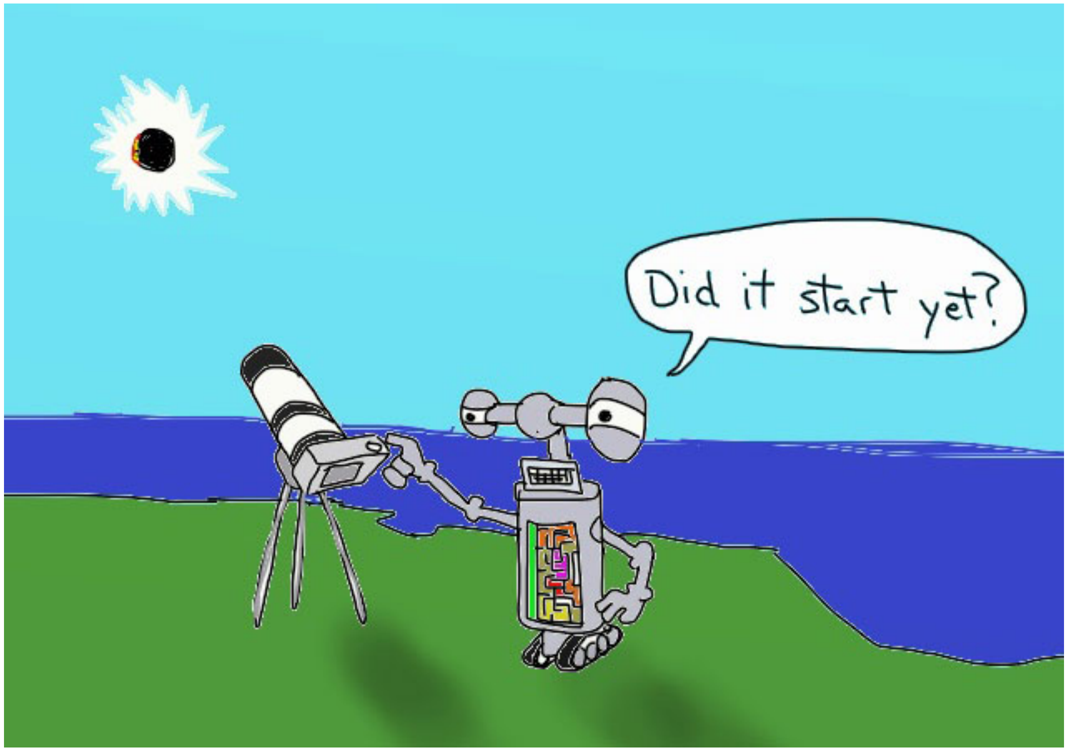
•The radius of a circle represents the mean lunar radius.

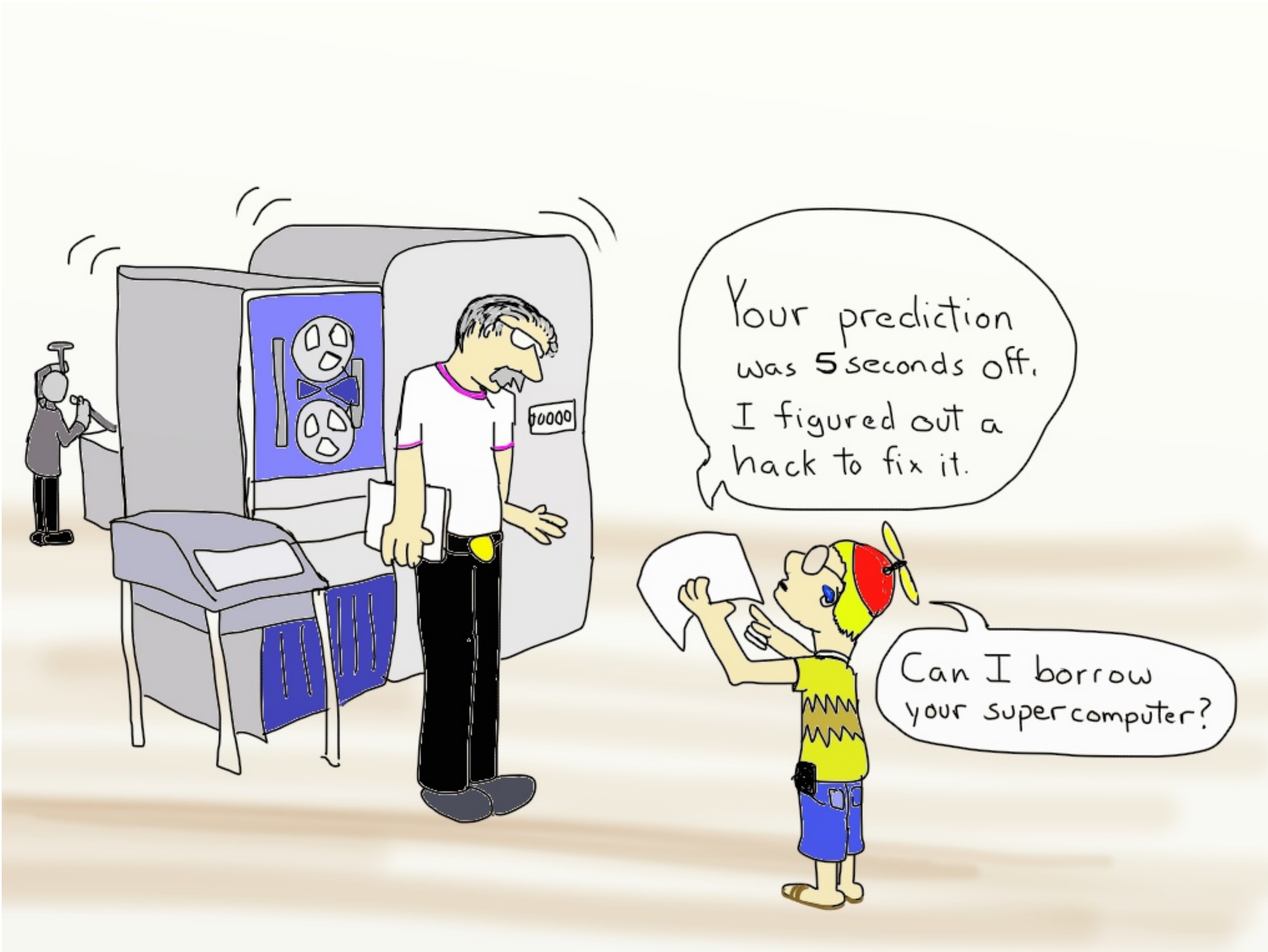
•For example, the NASA predictions use a lunar radius that is reduced from the IAU accepted value to account for valleys.

•Modern methods of eclipse prediction are accurate to a few seconds at the contact times.

- The greatest error in the calculations is now due to the lunar limb variations

Automated camera systems need a higher degree of precision.

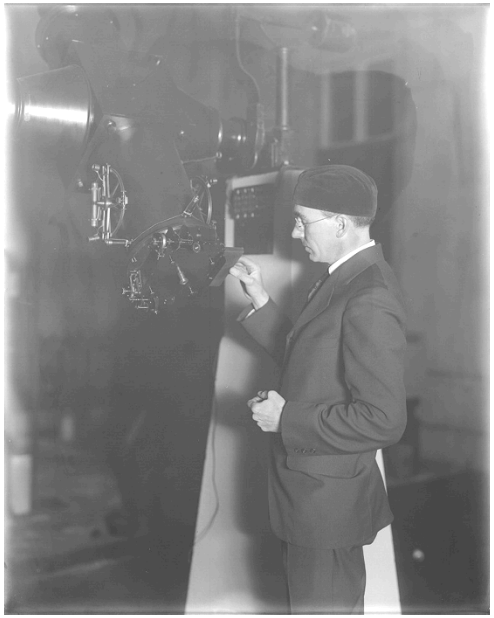



Your prediction was 5 seconds off. I figured out a hack to fix it.
Can I borrow your supercomputer?
00000

- Given a lunar limb profile one can determine corrections to the timing due to mountains and valleys.
- A procedure to determine corrections is discussed in past NASA eclipse publications.
    - We will discuss how to automate the process.

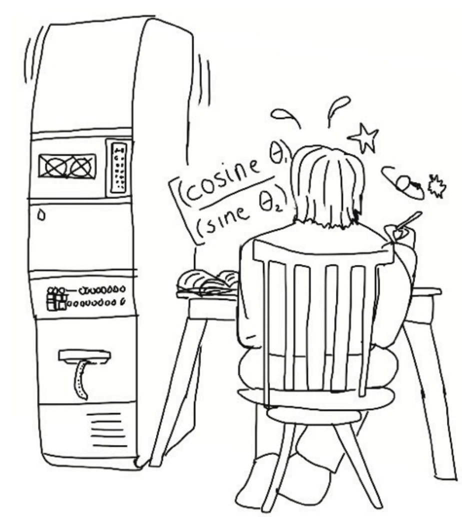
Step 1: Find Digital Lunar Profile

- Available online at the Centre de Données astronomiques de Strasbourg (
  - http://cdsweb.u-strasbg.fr/Cats.html)
  - The Marginal Zone of the Moon - Watts' Charts (Watts, 1963)
- Placed courtesy of Dave Herald.



Watt's Lunar Limb Profiles

- Watt's lunar limb profiles.
  - It contains a normalized binary array of librations (latitude, longitude), position angles, and deviations.
  - There are 1800 different profiles stored in the file.
  - It is a 39 megabytes FITS file.
- Newer profiles do exist
  - Result of lunar orbiters and some heavy number crunching.

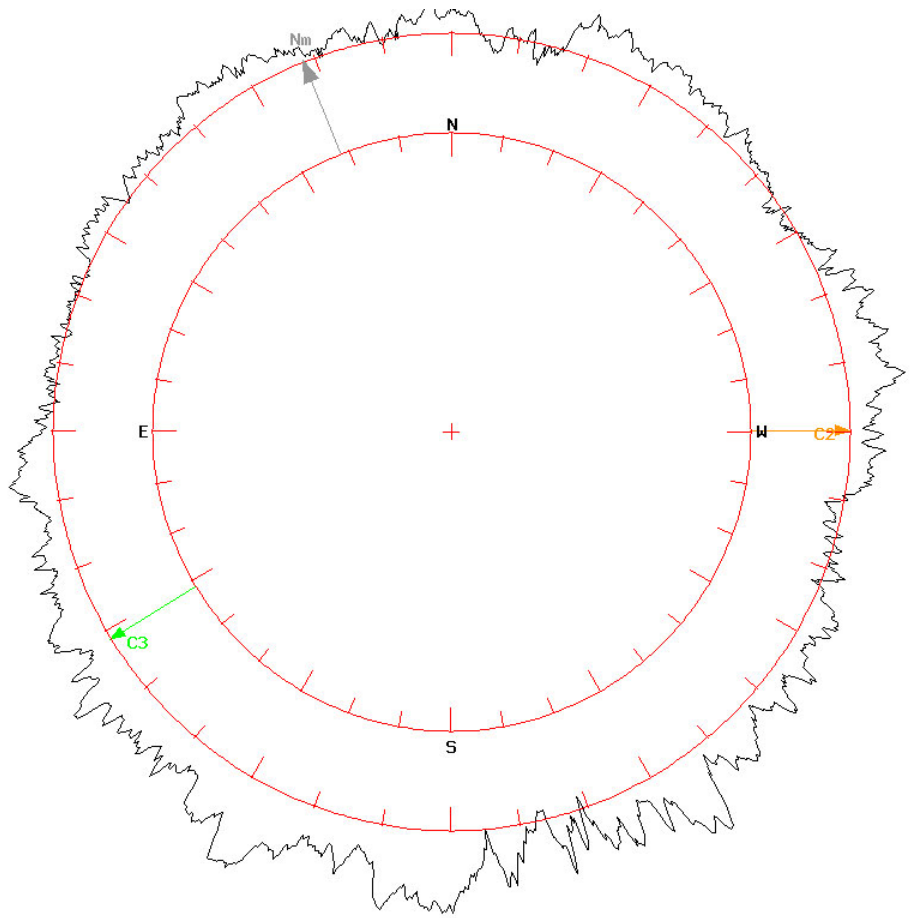


Step 2: Lunar Libration

Step 2: Lunar Libration

- Determine the lunar libration latitude and longitude for a given time and observer location.
- The latitude and longitude of libration are used to access a specific Lunar Profile.
  - Lunar profile is a list of position angles and deviations.
  - The deviation is a radial coordinate stored in seconds of arc from the mean lunar limb as seen from the center of figure.

Lunar Profile 60x

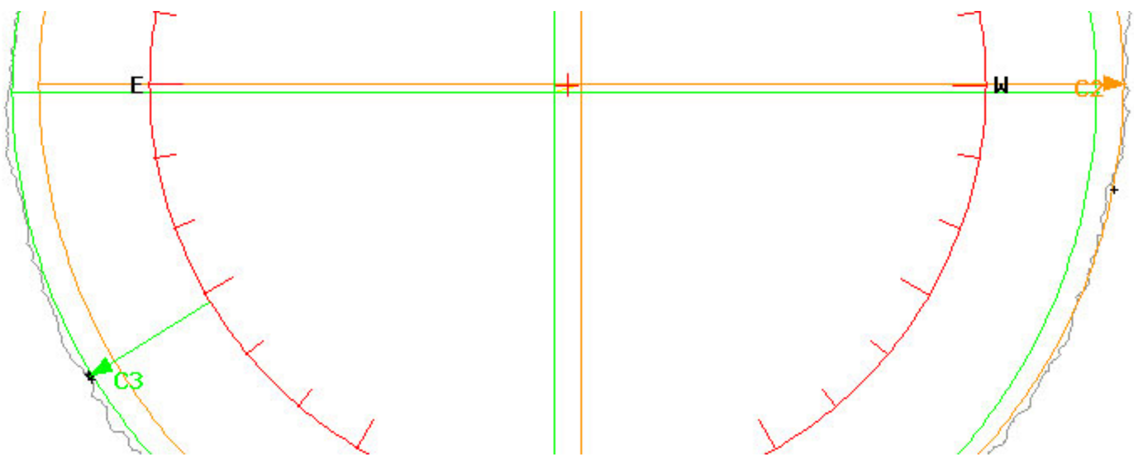


Step 3: Method

- The position angles for C2 and C3 give us the location where the solar disk is tangent to the lunar disk.
  - C2 red
  - C3 green

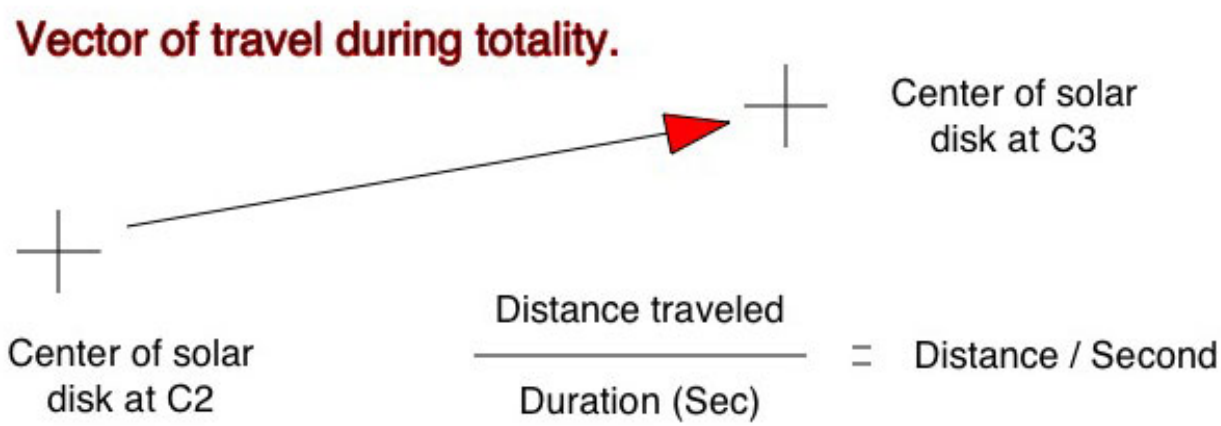
A) Given Angular size of solar disk.

B) Determine center points of solar disk for C2 and C3



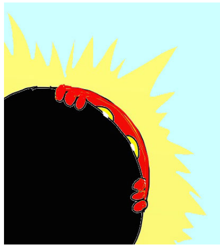
Method

- The center points of the solar disk at the C2 and C3 locations are used to establish a vector of travel.



Method Description

- Moving the center point of the solar disk along the vector at distances corresponding to 0.1 seconds.
- Compare the points on the resultant solar disk relative to the points from the profile.
- If all points of the solar disk are inside the lunar profile,
  - Move further along vector and compute again looking for the first instance of solar disk visibility. This will increase duration time.
  - Otherwise, move along vector in the other direction looking for the last instance of solar disk visibility. This will decrease duration time.

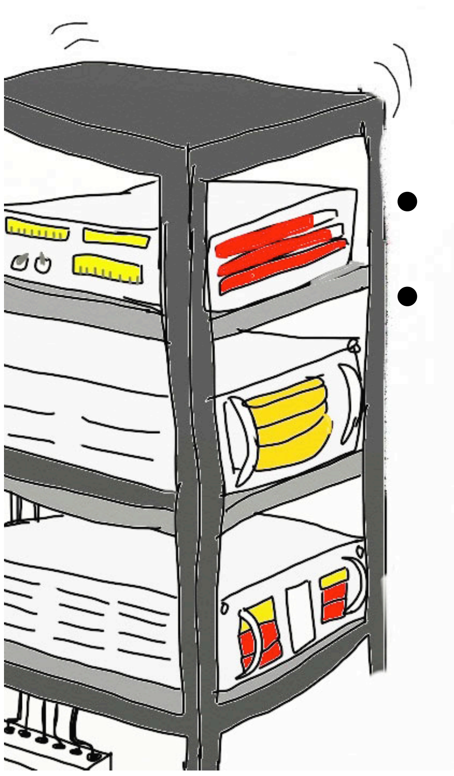


Profile Testing Routing

```
// isTouch will return true if any point along the lunar points is greater in distance
// from the solar center point ($Xs, $Ys) than the solar radius ($Srad)

 isTouch($Xs,$Ys,$Srad,$points) {
     global $testToler; //Tolerance distance for testing hit or miss.
    $hit = false;
    for ($ii=0; $ii<count($points); $ii+=2) {
      if ((distance($Xs,$Ys,$points[$ii],$points[$ii+1]) - $Srad) > $testToler) {
              $hit=true;
             $ii = count($points)+1;       }  }
   return $hit;
}
```

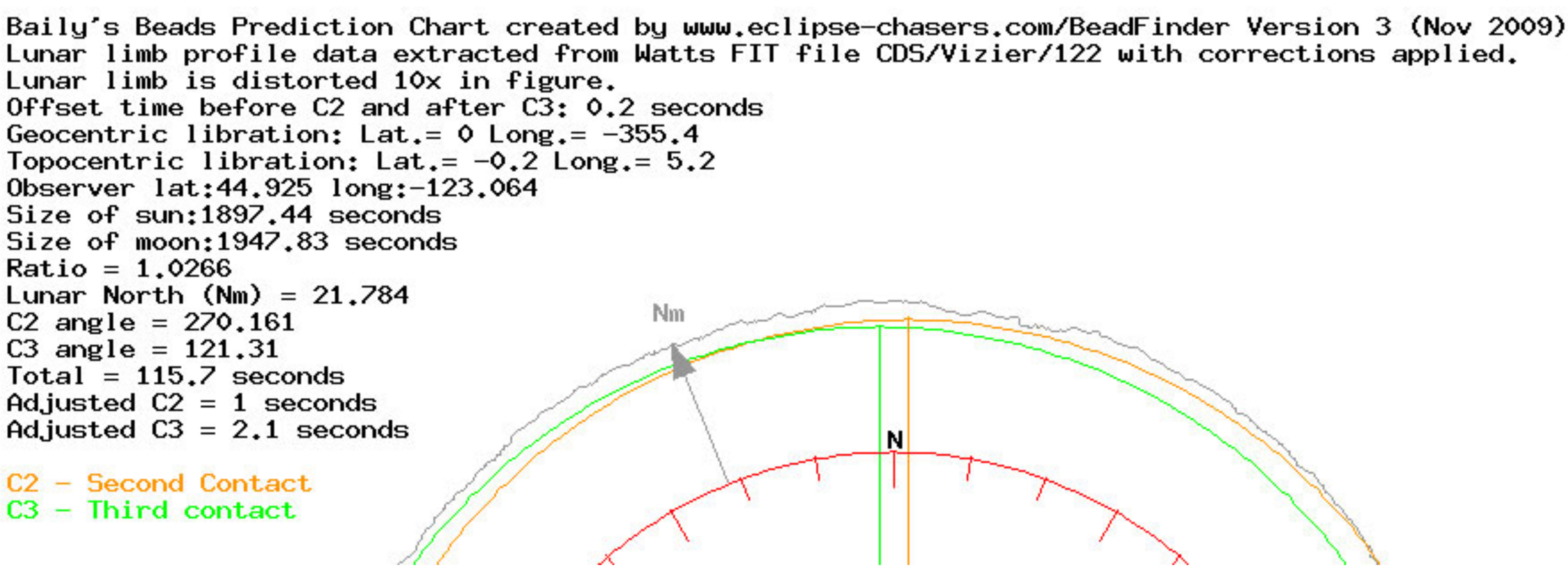
Profile Testing Module



- Minimize comparisons: No Need to test entire profile, just area near contact position angle.
  - +/- 20 degrees used in programming.
  - The result is more or less optimized for central path viewing, not edges!
- Corrections possible to accuracy of data.
- Half distance jump over algorithm used, start with larger time jump and half each time in opposite direction until “close enough”.

Method Finishes

- The resulting distance of movement of the center point corresponds directly to time.
- The difference found can then be applied to C2 or C3 to determine a new estimated contact time and location.

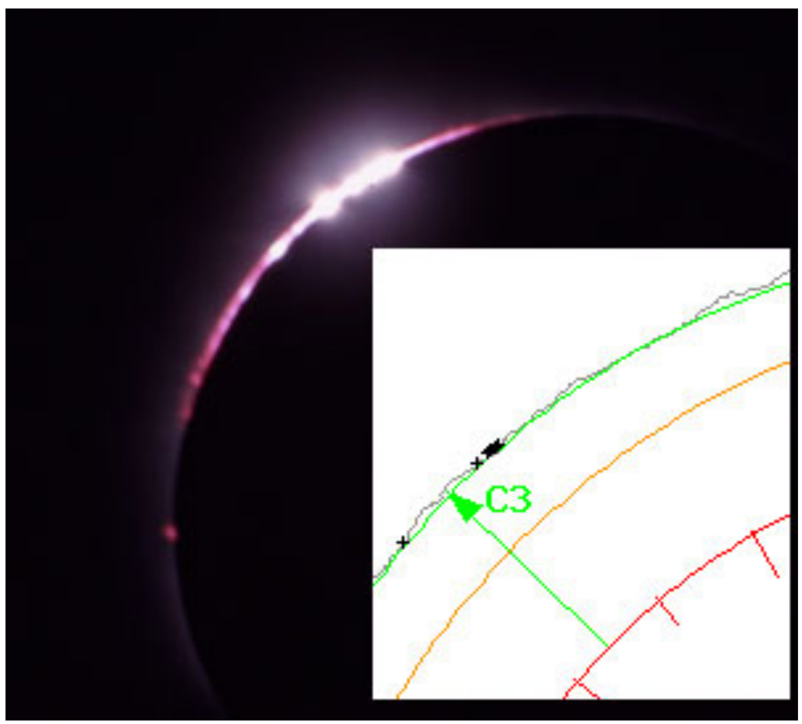


Issues that came up

- Lunar profile charts not completely accurate
  - Published correction methods for systematic errors in original profile. (Morrison/Appleby)
- Use of different mean lunar diameters and scales (IAU standard versus min. dia.)
- Raw computational requirements as related to online response desires.
- Not always accurate for N/S edges of path. Result was often a jagged edge with irregularities.

Initial Testing

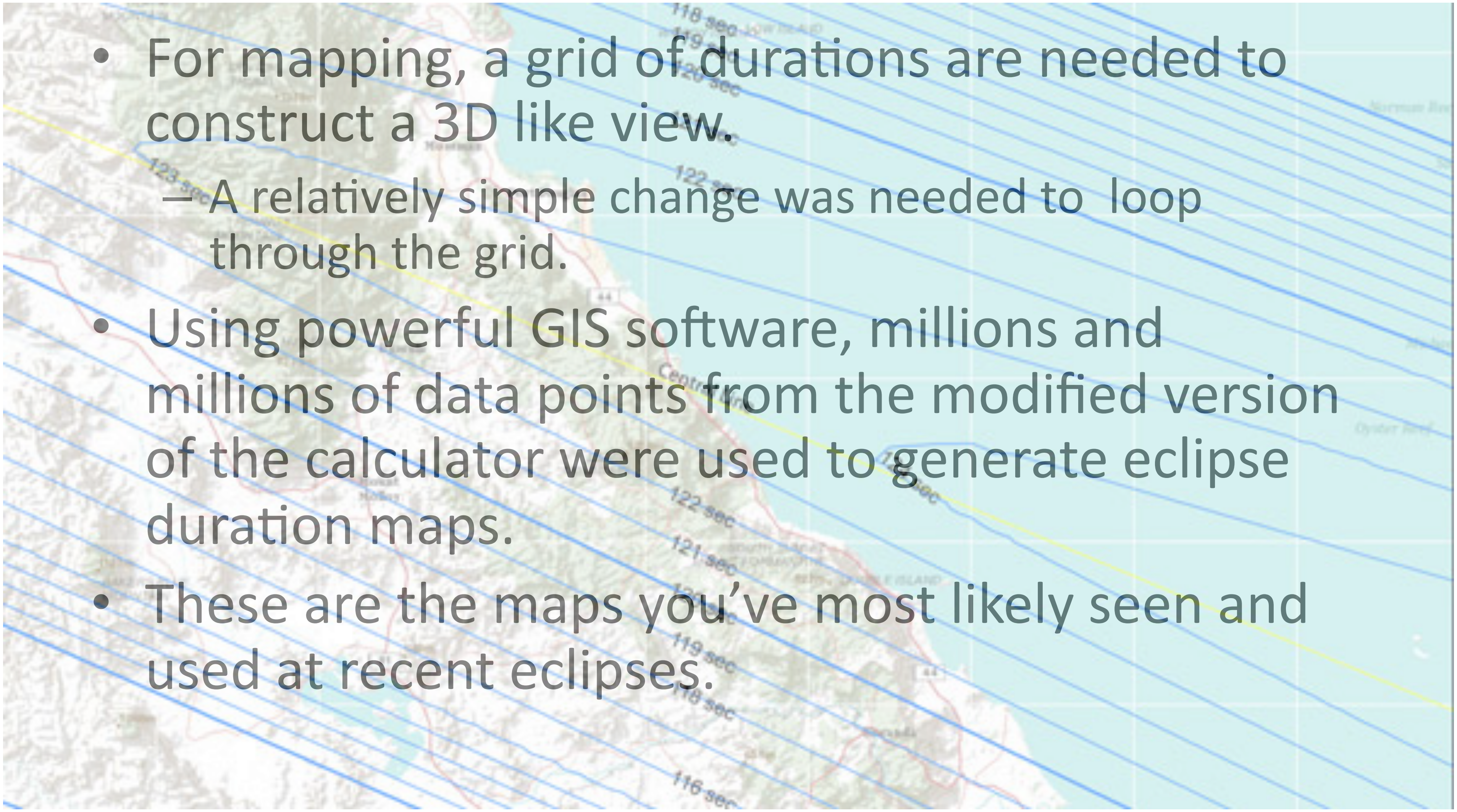
- To test this method, images of Baily's Beads were compared to expected bead locations given additional time before C2 and after C3.



Pushing the concept

- When the calculator was first written, the purpose was to refine the calculations for local circumstances.
- Another eclipse and computer enthusiast, Michael Zeiler, contacted me about using the calculator to create a grid of points.
  - He had a mapping application in mind.
  - His background was in GIS.

Mapping

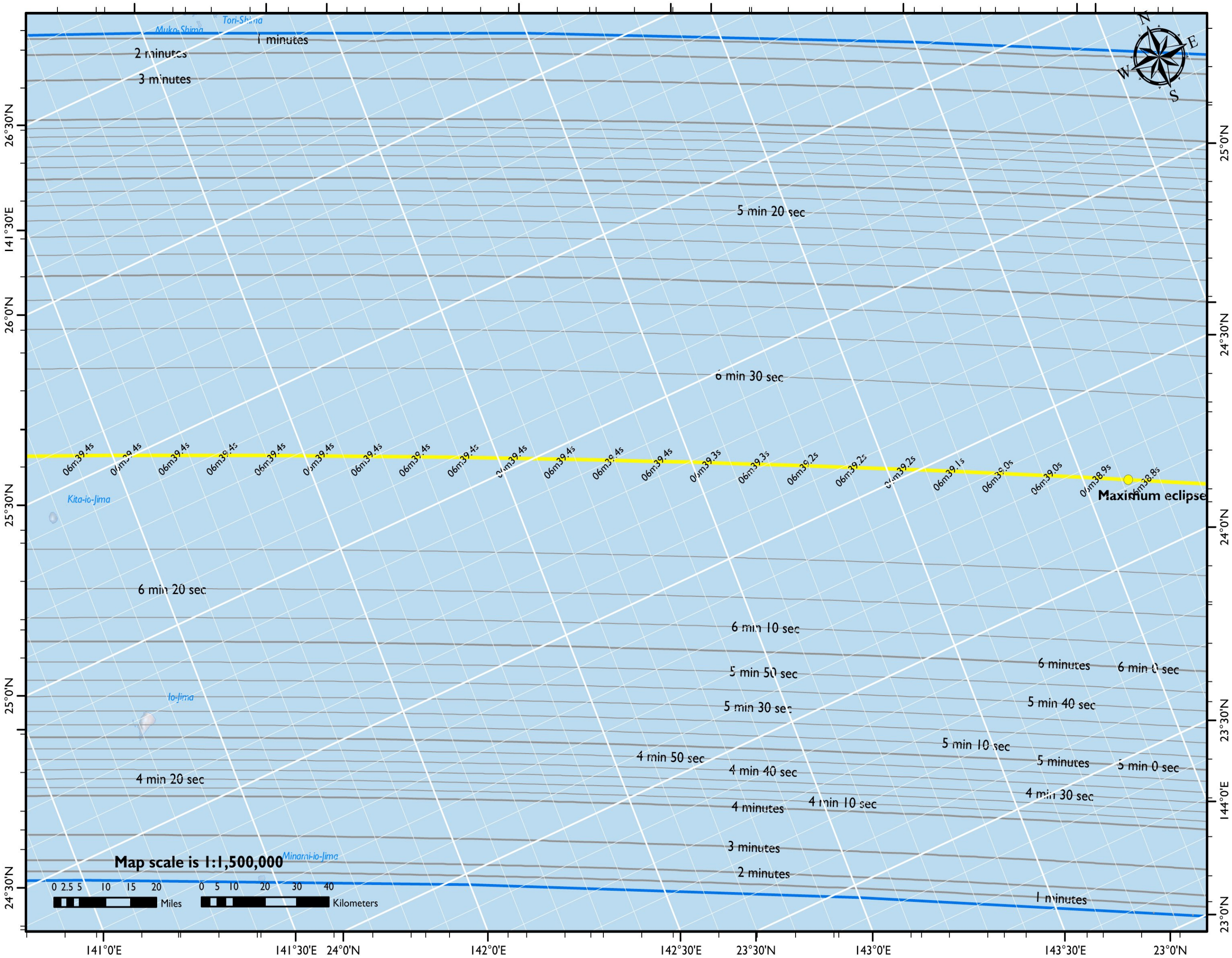


- For mapping, a grid of durations are needed to construct a 3D like view.
  - A relatively simple change was needed to loop through the grid.
- Using powerful GIS software, millions and millions of data points from the modified version of the calculator were used to generate eclipse duration maps.
- These are the maps you've most likely seen and used at recent eclipses.

Total Solar Eclipse of July 22, 2009

Detail: Longitude 141 E to 144 E

Map prepared by Michael Zeiler (mzeiler@esri.com)
Produced with ESRI ArcMap software using world shaded relief data from www.esri.com/arcgisonline
Eclipse path calculations by Fred Espanek, NASA Goddard Space Flight Center (www.mreclipse.com)
Grid points for for lines of equal duration calculated by Bill Kramer (www.eclipse-chasers.com)
Map projection is World Cylindrical Equal Area on WGS 1984 Spheroid



My ISP kept restarting the servers

The long range project was saved by Xavier Jubier creating a modification to his popular Solar Eclipse Maestro so that Micheal Zeiler could abuse his own processors.

Digital Lunar Profiles


space.com

- A newer set of data is available to replace the Watts Lunar profile.
- Created by David Herald (IOTA) it is the result of ray tracing the 3D lunar data provided by JAPAX and the Kaguya orbiter.
  - Sometimes called the Kaguya-Herald lunar profile David was kind enough to create the file in the same format as the Watts data (FITS) for the variable libration values.

Testing further?

- Do you have a video tape that shows Baily's Beads?
  - Known location?
  - Compare the video results with the predicted results obtained using the website or SEM software options.
  - Let me know if they matched up or were off.
    - bill@eclipse-chasers.com