# Moon Calculator

Version 6.0

Program and documentation by

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http://www.ummah.org.uk/ildl/mooncalc.html

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*"The sun must not catch up the moon, nor does the night outstrip the day. Each one is travelling in an orbit with its own motion"*
*(Al Qur'an 36:40)*

*"the sun and the moon (are subjected) to calculations"*
*(Al Qur'an 55:5)*

# Contents

# 0. Copyright



Data/graphics/maps produced by MoonCalc may be used if accompanied by the following acknowledgement:

"data/graphics/map* from MoonCalc 6.0 by Dr. Monzur Ahmed."

(*as appropriate)

Data produced by MoonCalc must not be used for commercial purposes.

If MoonCalc data are used on a Web page, a link may be made to one or both of the MoonCalc homepages:

http://www.starlight.demon.co.uk/mooncalc
http://www.ummah.org.uk/ildl/mooncalc.html

MoonCalc may be copied and distributed freely as long as all files are copied and no charge is made (other than a nominal charge for media). The program must be distributed as its ORIGINAL and UNMODIFIED zip file moonc60.zip).

No alterations should be made to the program, documentation or data files apart from the atlas database, TOWNS.DAT.

Although MoonCalc may be distributed freely, it is not 'Public Domain' nor is it 'Freeware'. All rights remain with the author, Dr. Monzur Ahmed.

# 1. Introduction

MoonCalc provides information relating to the position, age, phase, orientation, appearance and visibility of the moon for any given date, time and location on earth. It also provides the Julian Day Number, Magnetic Declination, time and direction of moonrise and moonset, interval between sunset and moonset, interval between sunrise and moonrise, date/time of astronomical new moon (conjunction), full moon, apogee and perigee and predicts the likelihood of visualising the young moon from a particular location. Data pertaining to solar and lunar eclipses in any year are also shown. MoonCalc provides Hijri calendar data including location dependent Hijri date conversion using predicted crescent visibility. Automatic local and regional (tri-zonal) Hijri calendar tabulation is possible.

The program can scan the globe at the start of any lunar month to find the location, date/time and direction of earliest crescent sighting using a variety of ancient and modern moon sighting criteria. The program is able to draw world maps (flat and spherical projections) showing areas of the globe where the young moon is likely to be seen.

Graphical displays showing the position of the moon on a star chart and the position of the moon in a simulated local sky (horizon view or traditional circular sky-chart view) can be produced and printed out. A close-up of the near side of the moon (showing orientation of the moon's limbs and position of the lunar craters), correct for a given observation site, is also provided. This close up takes into account the effect of libration and 'limb shortening' (optional). A graph of lunar libration for an entire month can be plotted.

There is a choice of either topocentric/geocentric co-ordinates and apparent/geometric sunset. Correction for atmospheric refraction is optional.

The program has a built in atlas database which stores latitude and longitude data of upto 1000 cities (ships with over 100 cities already entered). There are many user-configurable features.

# 2. Getting Started

## 2.1 Minimum system requirements

The minimum system requirements needed to run MoonCalc are:

- 386 based PC or compatible running DOS (486DX or better recommended)
- One floppy drive (hard drive strongly recommended)
- At least 500K free on disk for temporary storage (floppy should not be write protected)
- Colour VGA display or better (partial support for CGA, EGA and Hercules displays)

## 2.2 Files included

The following 14 files should be included on the distribution disk or be present after unzipping the moonc60.zip archive:

| | |
|---|---|
| MOONC60.EXE | The main program |
| DEFAULTS.MC | Stores initial program default values |
| TOWNS.DAT | Database of town data, can be modified* |
| STARDATA.DAT | Data of 9025 stars from Yale Brightstar Database |
| BRIGHTST.DAT | Data of 1st magnitude stars |
| MOONFACE.DAT | Data to generate lunar craters |
| CONSTELN.DAT | Data to generate constellation lines |
| WORLDMAP.DAT | Data to generate word map |
| MAGMODEL.DAT | Model data for calculating Magnetic Declination |
| SVGA256.BGI | Required to display 600x800 and 1024x768 graphics modes (BGI driver copyright Borland Intl.) |
| MOONC60.BMP | Nice icon for use as windows shortcut |
| README.TXT | Documentation for MoonCalc in ASCII format |
| README.PDF | This file! |
| WHATSNEW.TXT | Lists new features + history of release dates. |

The following file is generated by the program:

| | |
|---|---|
| SCAN.DAT | Temporary file produced by program during scanning. |

(* in versions prior to 5.0, this file was called DATA.PTC and had a different structure)

## 2.3 Making Backups

As with all new programs, it is advisable to make backup copies of all the files. You should then write protect the original disk and keep it in a safe place. Use only the backed up disk.

## 2.4 Running MoonCalc on a floppy drive system

<u>DOS</u>

Place your disk in, say, drive A. Now make sure you have the A:> prompt showing:

A:>

Type MOONC60 <CR> and the program will start with standard graphics mode.
MOONC60 S <CR> will start program with graphics in 600x800 mode.
MOONC60 H <CR> will start program with graphics in 1024x768 mode.

The floppy should NOT be write protected as MoonCalc will need to access the disk for temporary storage.

Windows

Place your disk in, say, drive A. Use Windows explorer or File Manager to log onto drive A. Then double-click on the MOONC60.EXE file.

## 2.5 Installing and running MoonCalc on a hard drive system

DOS

Let us assume that your hard drive is called drive C. You should initially make a directory called e.g. MOON:

md c:\moon <CR>

Put the floppy disc containing the program into drive A. Copy all the files from the floppy disc into the MOON directory:

copy a:*.* c:\moon <CR>

Ensure that you are logged onto the MOON directory:

cd c:\moon <CR>

Now type MOONC60 <CR> and the program will start with standard graphics mode.
MOONC60 S <CR> will start program with graphics in 600x800 mode.
MOONC60 H <CR> will start program with graphics in 1024x768 mode.

Windows

MoonCalc may be run in a DOS box under Windows 3.1 or Windows 95/98. This is the preferred option. You can have a desktop shortcut if you wish.

When using MoonCalc under Windows make sure that the 'Working' or 'Start in' property of the desktop shortcut points to the directory that contains the MoonCalc files. This tells MoonCalc where to find the associated files.

The 'Cmd line' property of the shortcut should be....
MOONC60 to start program with standard graphics mode (640x480).
MOONC60 S to start program with graphics in 600x800 mode.
MOONC60 H to start program with graphics in 1024x768 mode.

The latter two options may not work on all systems and I do not recommend the last one unless you have a very good monitor!

# 3. Using the Program

When the program is run the following MAIN MENU is displayed:

```
IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
I  Moon Calculator                Version 6.0  I
I  By Dr. Monzur Ahmed      (c) May 93/Oct 01  I
I                                              I
I----------------------------------------------I
I               M A I N   M E N U              I
I----------------------------------------------I
I                                              I
I    1. Summary tables of Moon Data            I
I    2. Moon position on Starchart (Dec vs RA) I
I    3. Simulation of Local Sky (Alt vs Azi)   I
I    4. Close-up of Moon                       I
I    5. First Crescent Sighting (Global Scan)  I
I    6. Hijri Calendar Tabulation              I
I    7. Libration Graph                        I
I    8. Eclipses                               I
I    9. Add/ Delete/ Change Atlas Data         I
I    0. Change Options                         I
I    X. Exit to DOS                            I
I                                              I
I    Use cursor keys or 0-9 to make choice     I
IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
```

You may make a choice from this menu either by using the cursor keys to highlight the desired option and pressing enter or by pressing 1,2,3,4,5,6,7,8,9,0 or X directly.

## 3.1 Option 1. Summary tables of Moon Data

When this option is chosen, the following screen will appear:

```
IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
ICurrent Place = BIRMINGHAM                   I
IPress ENTER to accept or type in new place   I
IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII

NAME OF PLACE ?
```

```
IIIIIIIIIIIIIIIIIIIIIIIIII
I     ABERDEEN           I
I     ACCRA              I
I     ALGIERS            I
I     AMSTERDAM          I
I     ANKARA             I
I     ATHENS             I
I     BAGHDAD            I
I     BANGKOK            I
I     BELFAST            I
I     BERLIN             I
I     BERNE              I
I     BIRMINGHAM      << I
I     BOGOTA             I
I     BONN               I
I     BRADFORD           I
I     BRASILIA           I
I     BRUSSELS           I
IIIIIIIIIIIIIIIIIIIIIIIIII
IIIIIIIIIIIIIIIIIIIIIIIIII
I  CURSORS & PAGE UP/DN  I
I     to move pointer    I
IIIIIIIIIIIIIIIIIIIIIIIIII
```

Initially, the location has to be entered. The program comes with a built in database of about 100 cities (you can add to or modify this database, see section 3.9). The places that are already in the database are listed in a scrolling window on the right. You can choose a place from the database either by highlighting it with the cursor keys and pressing ENTER or by typing the name of the place and pressing ENTER.

If you type in the name of a place which is not in the database, the program will ask you to enter the latitude, longitude, time zone and height above sea level of this place. You will also be asked *if* Summer Time operates at this location. (Note that the rules determining *when* Summer Time starts and ends can be altered using 'Change Options' from the Main Menu; see section 3.10.3). The latitude and longitude of most major towns can be obtained from a good world atlas. The time zone of the place is the time difference in hours between the location and Greenwich.

Next, the program will ask you to enter the year, month, date and time (hours, min and sec) for which you wish to calculate the position of the moon.

Once all this preliminary information has been entered, the computer will display the message 'Calculation in progress..' before showing four tables of data (each table occupying a whole screen).

Press ENTER repeatedly to cycle through the four tables of data:-

### 3.1.1 Screen 1 of 4

Shows data pertaining to current time as entered by the user following the instructions above, eg for Birmingham (UK) on 21st Jan 1996 at 14:50 hrs:

```
  IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
  I BIRMINGHAM 52:30N 1:55W TZ:0.0 Ht:236m JD:2450103.5        Topo   Refrac ON I
  I Mag Dec:     -4.655 -4d   39m 20s                 Date:    Sun 21 Jan  1996 I
A I Delta T (TD-UT):     0h   01m 02s                 Time:    14h  50m 00s LT  I
  I Apparent Sunrise:    8h   01m 49s LT   Apparent Sunset:    16h  36m 21s LT  I
  I-----------------------------------1 of 4------------------------------------I
  I Moon Alt:    21.816  21d  48m 59s      Moon Azi:  205.118  205d 07m 05s     I
  I Moon Dec:   -12.564 -12d  33m 51s      Moon RA:    21.135  21h  08m 05s     I
  I Sun Alt:     10.523  10d  31m 25s      Sun Azi:   215.843  215d 50m 34s     I
B I Sun Dec:    -19.970 -19d  58m 12s      Sun RA:     20.204  20h  12m 14s     I
  I Rel Alt:     11.293  11d  17m 34s      Rel Azi:   -10.725 -10d  43m 29s     I
  I Elongation:  15.304  15d  18m 13s      Moon Age:   25.99h  1D   2H  0M      I
  I Phase:0.0194  Mag: -5.58  Width:0.59m  Semi-Diam:0.279 Distance:359942.24km I
  I-----------------------------------------------------------------------------I
  I Moon Rise:           8h   06m 14s LT   Azimuth:            110d 44m 44s     I
C I Moon Set:            18h  27m 14s LT   Azimuth:            252d 03m 41s     I
  I Sunrise-Moonrise:    0h   04m 25s      Sunset-Moonset:     1h   50m 52s     I
  I-----------------------------------------------------------------------------I
  I New Moon:            20 Jan  1996      JDE: 2450103.0357   12h  51m 28s TD  I
  I Full Moon:           4  Feb  1996      JDE: 2450118.1658   15h  58m 45s TD  I
D I Perigee:             19 Jan  1996      JDE: 2450102.4638   23h  07m 52s TD  I
  I Apogee:              1  Feb  1996      JDE: 2450115.1561   15h  44m 51s TD  I
  I-----------------------------------------------------------------------------I
E IENTER:More [H]elp +/-:±Month DEL/INS:±Day END/HOME:±Hr DN/UP:±Min SPACE:Menu I
  IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
```

The screen is divided into 5 areas:

A: Shows name of chosen location, latitude/longitude/time zone/height above sea level of chosen location as entered plus the date and time as entered. 'LT' next to the time indicates Local Civil Time ('UT' indicates Universal Time). A '*' next to LT (not shown in the example above) indicates that one hour has been added for Daylight Saving Time/Summer Time. The Julian Day number (JD) of the entered date is displayed on the top line. The top right of the screen also indicates whether Topocentric (Topo), as shown above, or Geocentric (Geo) co-ordinates are in use. Also there is an indication of whether there is correction for atmospheric refraction (Refrac ON or Refrac OFF).

The Magnetic Declination (Mag Dec) for the entered time/place is shown. Magnetic Declination is the direction of magnetic north relative to true north and varies with time and location. A positive value indicates that magnetic north is east of true north whilst a negative value indicates that magnetic north is west of true north. The geomagnetic field model used in MoonCalc 6.0 is most accurate between 1995 and 2005 although a value will be shown for years in the range 1990-2010.

Delta T is the difference between Terrestrial Dynamical Time (TD) and Universal Time (UT). Delta T cannot be predicted accurately for the future but retrospective values can be calculated. MoonCalc uses a combination of empirical equations and look-up tables to calculate Delta T. The sunrise and sunset times for the entered date are also shown. The user can choose whether to display apparent or geometric sunrise/set - see section 3.10.13.

B: The main part of table. Shows the moon/sun altitude, moon/sun azimuth, moon/sun declination, moon/sun right ascension, relative altitude, relative azimuth, elongation, age of the moon, moon phase, moon magnitude, crescent width (Width) in arc minutes, semi-diameter (semi-diam) of moon and earth-moon distance for the location, date and time entered by the user.

*ALL DISPLAYED ALTITUDES ARE MEASURED TO THE CENTRE OF THE BODY. TO OBTAIN ALTITUDE TO LOWER LIMB OF MOON, SUBTRACT SEMI-DIAMETER FROM ALTITUDE TO CENTRE. ALL AZIMUTHS ARE MEASURED CLOCKWISE RELATIVE TO TRUE NORTH (NOT MAGNETIC NORTH).*

C: Shows the time and direction (azimuth) of moon rise and moon set for that day and location. The interval between apparent sunset and moonset and the interval between apparent sunrise and moonrise are also shown.

D: Shows the date, time and Julian Ephemeris Day (JDE) of nearest astronomical new moon (conjunction), full moon, apogee and perigee. Note that the times have 'TD' next to them indicating that times are given as Terrestrial Dynamical Time. Remember TD is *not* the same as your local time. The difference between TD and GMT (or UT) is called Delta T and is currently just over 1 minute. The new/full moon times are accurate to a few seconds whilst the apogee/perigee times are accurate to a couple of minutes. If perigee occurs near conjunction it may be possible to see a younger crescent than usual.

E: Prompt line indicating that you should press....

ENTER to see all 4 tables of data in sequence,
H or F1 for help screen (meaning of abbreviations, brief definitions etc),
+/- to increase/decrease month,
DELETE/INSERT to increase/decrease day,
END/HOME to increase/decrease hour,
PAGE UP/DOWN to increase/decrease minute and
SPACE to return to the main menu.

## 3.1.2 Screen 2 of 4

Shows data pertaining to *sunset* on that day:

```
  IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
  I BIRMINGHAM 52:30N 1:55W TZ:0.0 Ht:236m JD:2450103.5        Topo   Refrac ON I
  I Mag Dec:     -4.655 -4d   39m 20s                Date:     Sun 21 Jan  1996 I
A I Delta T (TD-UT):     0h   01m 02s                Time:     14h  50m 00s LT  I
  I Apparent Sunrise:    8h   01m 49s LT  Apparent Sunset:     16h  36m 21s LT  I
  I---------------------------------2 of 4----------------------------------I
  I AT APPARENT SUNSET>                                                         I
  I New Moon Visibility (Yallop/-5,q0.790) A: Easily visible                    I
  I Moon Alt:     12.619  12d  37m 09s      Moon Azi:  229.693  229d 41m 33s     I
B I Sun Alt:      -0.667 -0d   40m 01s      Sun Azi:   237.962  237d 57m 45s     I
  I Rel Alt:      13.286  13d  17m 11s      Rel Azi:    -8.270 -8d   16m 12s     I
  I Elongation:   16.126  16d  07m 34s      Moon Age:   27.77h  1D   3H  46M     I
  I Phase:0.0219  Mag: -5.67  Width:0.66m  Semi-Diam:0.278 Distance:360179.99km I
  I-------------------------------------------------------------------------I
  I Moon Rise:           8h   06m 14s LT   Azimuth:            110d 44m 44s     I
C I Moon Set:            18h  27m 14s LT   Azimuth:            252d 03m 41s     I
  I Sunrise-Moonrise:    0h   04m 25s      Sunset-Moonset:     1h   50m 52s     I
  I-------------------------------------------------------------------------I
  I New Moon:            20 Jan  1996      JDE: 2450103.0357   12h  51m 28s TD  I
  I Full Moon:           4  Feb  1996      JDE: 2450118.1658   15h  58m 45s TD  I
D I Perigee:             19 Jan  1996      JDE: 2450102.4638   23h  07m 52s TD  I
  I Apogee:              1  Feb  1996      JDE: 2450115.1561   15h  44m 51s TD  I
  I-------------------------------------------------------------------------I
E IENTER:More [H]elp +/-:±Month DEL/INS:±Day END/HOME:±Hr DN/UP:±Min SPACE:Menu I
  IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
```

Areas A, C, D and E remain the same. The data in area B now relates to *local sunset* on the day entered by the user.

The screen indicates moon altitude, moon azimuth, sun altitude, sun azimuth, relative altitude, relative azimuth, elongation, age of the moon, phase, magnitude, crescent width, moon semi-diameter and earth-moon distance. The above information is useful in assessing the likelihood of visualising the new moon after sunset. In fact, the program uses one of several well known moon sighting criteria (in the example above Yallop's criterion is being used) to predict if the new moon would be visible from the user's location after sunset on that day. For more information on crescent sighting criteria, see section 3.5. To change the sighting criterion see section 3.10.6.

In the example above, the moon's characteristics (in particular altitude and crescent width) satisfy Yallop's criterion for visibility- hence the program indicates moon should be 'A:easily visible' on 21 Jan 1996 in Birmingham. Enter the above example, go to screen 2 and press the INSERT key to go back a day to 20 Jan 1996. You will see that on 20 Jan 1996 the moons characteristics do not satisfy Yallop's criterion and so the program declares that the moon is 'Not Visible' that evening.

<u>3.1.3 Screen 3 of 4</u>

Shows data pertaining to a time that day when the sun is approximately 5 degrees below the horizon:

```
  IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
  I BIRMINGHAM 52:30N 1:55W TZ:0.0 Ht:236m JD:2450103.5        Topo   Refrac ON I
  I Mag Dec:     -4.655 -4d   39m 20s                Date:    Sun 21 Jan  1996 I
A I Delta T (TD-UT):     0h   01m 02s                Time:    14h  50m 00s LT  I
  I Apparent Sunrise:    8h   01m 49s LT   Apparent Sunset:    16h  36m 21s LT  I
  I-----------------------------------3 of 4----------------------------------I
  I WHEN SUN IS ~5° BELOW HORIZON>                   Time:    17h  04m 04s LT  I
  I                                         "Best" Time:    17h  25m 38s LT  I
  I Moon Alt:     9.472  9d   28m 21s      Moon Azi:  235.542  235d 32m 33s     I
B I Sun Alt:     -5.002 -5d   00m 09s      Sun Azi:   243.350  243d 21m 02s     I
  I Rel Alt:     14.475  14d  28m 30s      Rel Azi:    -7.808 -7d   48m 29s     I
  I Elongation:  16.354  16d  21m 15s      Moon Age:   28.23h  1D   4H  14M     I
  I Phase:0.0225  Mag: -5.69  Width:0.67m  Semi-Diam:0.277 Distance:360243.50km I
  I---------------------------------------------------------------------------I
  I Moon Rise:           8h   06m 14s LT   Azimuth:           110d 44m 44s     I
C I Moon Set:            18h  27m 14s LT   Azimuth:           252d 03m 41s     I
  I Sunrise-Moonrise:    0h   04m 25s      Sunset-Moonset:     1h   50m 52s     I
  I---------------------------------------------------------------------------I
  I New Moon:            20 Jan  1996      JDE: 2450103.0357   12h  51m 28s TD  I
D I Full Moon:           4  Feb  1996      JDE: 2450118.1658   15h  58m 45s TD  I
  I Perigee:             19 Jan  1996      JDE: 2450102.4638   23h  07m 52s TD  I
  I Apogee:              1  Feb  1996      JDE: 2450115.1561   15h  44m 51s TD  I
  I---------------------------------------------------------------------------I
E IENTER:More [H]elp +/-:±Month DEL/INS:±Day END/HOME:±Hr DN/UP:±Min SPACE:Menu I
  IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
```

Again areas A, C, D and E are unchanged. Area B now shows data when the geocentric altitude of the sun is 5 degrees below the horizon. At this time the sky is sufficiently dark to optimise the likelihood of seeing a new moon. The time when the sun is 5 degrees below the horizon is shown together with moon altitude, moon azimuth, sun altitude, sun azimuth, relative altitude, relative azimuth, elongation, age of the moon, phase, magnitude, crescent width, moon semi-diameter and earth-moon distance. In the example shown above, the observer should look for the new moon after sunset at about 17:04. The crescent moon should be seen in the western sky (azimuth 235.5 degrees). The moon will be about 28.2 hours old and will be about 9-10 degrees above the horizon (moon altitude 9.47 degrees).

Note that "best time" is also shown (if the moon sets after the sun). Best time is "sunset + 4/9*lag". This simple rule was derived by Yallop (ref 24) from the work of Bruin (ref 10, also see section 3.5.1).

### 3.1.4 Screen 4 of 4

This screen shows Hijri calendar data:

```
  IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
  I BIRMINGHAM 52:30N 1:55W TZ:0.0 Ht:236m JD:2450103.5        Topo   Refrac ON I
  I Mag Dec:     -4.655 -4d   39m 20s                  Date:    Sun 21 Jan  1996 I
A I Delta T (TD-UT):     0h   01m 02s                  Time:    14h  50m 00s LT  I
  I Apparent Sunrise:    8h   01m 49s LT   Apparent Sunset:     16h  36m 21s LT  I
  I----------------------------------4 of 4---------------------------------I
  I HIJRI CALENDAR DATA>          Criterion: Yallop/-5 [A or B]                  I
  I                                                                              I
  I 1 Ramadhan 1416 AH            starts at sunset on:        21 Jan  1996       I
B I                               & ends at sunset on:        22 Jan  1996       I
  I Hijri Day Number:    501666                                                  I
  I Islamic Lunation No: 16989            Astronomical Lunation No: 904          I
  I Crescent first seen: 21 Jan  1996     [L]ocal or [T]rizonal dates for year I
  I-----------------------------------------------------------------------------I
  I Moon Rise:           8h   06m 14s LT   Azimuth:             110d 44m 44s     I
C I Moon Set:            18h  27m 14s LT   Azimuth:             252d 03m 41s     I
  I Sunrise-Moonrise:    0h   04m 25s      Sunset-Moonset:      1h   50m 52s     I
  I-----------------------------------------------------------------------------I
  I New Moon:            20 Jan  1996      JDE: 2450103.0357    12h  51m 28s TD  I
  I Full Moon:           4  Feb  1996      JDE: 2450118.1658    15h  58m 45s TD  I
D I Perigee:             19 Jan  1996      JDE: 2450102.4638    23h  07m 52s TD  I
  I Apogee:              1  Feb  1996      JDE: 2450115.1561    15h  44m 51s TD  I
  I-----------------------------------------------------------------------------I
E IENTER:More [H]elp +/-:±Month DEL/INS:±Day END/HOME:±Hr DN/UP:±Min SPACE:Menu I
  IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
```

Areas A, C, D and E remain the same. Area B shows Hijri calendar data. The Hijri date is calculated using predicted lunar visibility for the user's location. In the above example, Yallop's criterion is being used to calculate Hijri data. However, any of the 13 moonsighting criteria that MoonCalc currently supports may be used (see 3.5.1 and 3.10.6) making MoonCalc the most accurate and versatile Hijri date converter available.

***PLEASE NOTE THAT THE RGO 67 CRITERION AS IMPLEMENTED IN MOONCALC IS NOT SUITABLE FOR GENERAL HIJRI DATE CONVERSIONS. (THE CRITERION IS SUITABLE FOR DETERMINING THE LOCATION OF *EARLIEST* CRESCENT VISIBILITY ON A GLOBAL SCAN).***

In the above example, for Birmingham, 1st Ramadhan 1416 AH begins at sunset on 21st Jan 1996 and ends at sunset on 22nd Jan 1996. The corresponding Hijri day number is 501666 and Islamic lunation number is 16989. The Gregorian date on which the crescent is first seen for that month is also displayed.

1 Muharram 1AH is taken to begin at sunset on 15th July 622 CE and end at sunset on 16th July 622 CE. The Hijri day number uses sunset 15th July 622 CE as the epoch (day 1). Islamic lunation number is the number of lunations that have elapsed since Muharram 1 AH (lunation 1).

Pressing 'L' gives a local Hijri calendar for a whole year. Pressing 'T' gives a Trizonal calendar for a whole year. There is more information on local and Trizonal Hijri calendars in section 3.6.1 and 3.6.2.

In any of these 4 screens it is possible to see the data for the next/previous month, day, hour or minute using the following keys:

| | |
|---|---|
| +/- | increase/ decrease MONTH |
| DEL/INS | increase/ decrease DAY |
| END/HOME | increase/ decrease HOUR |
| PAGE DN/UP | increase/ decrease MINUTE |

***REMEMBER THE ABOVE KEY COMBINATIONS***
***THEY ARE CONVENIENTLY SITUATED ON MOST STANDARD KEYBOARDS.***
***THEY ARE CONSISTENT THROUGHOUT THE PROGRAM***

<u>3.1.5 Earliest new moon sighting for a given location</u>

To find the date and time of earliest sighting of the new moon for a given location, use the following steps:

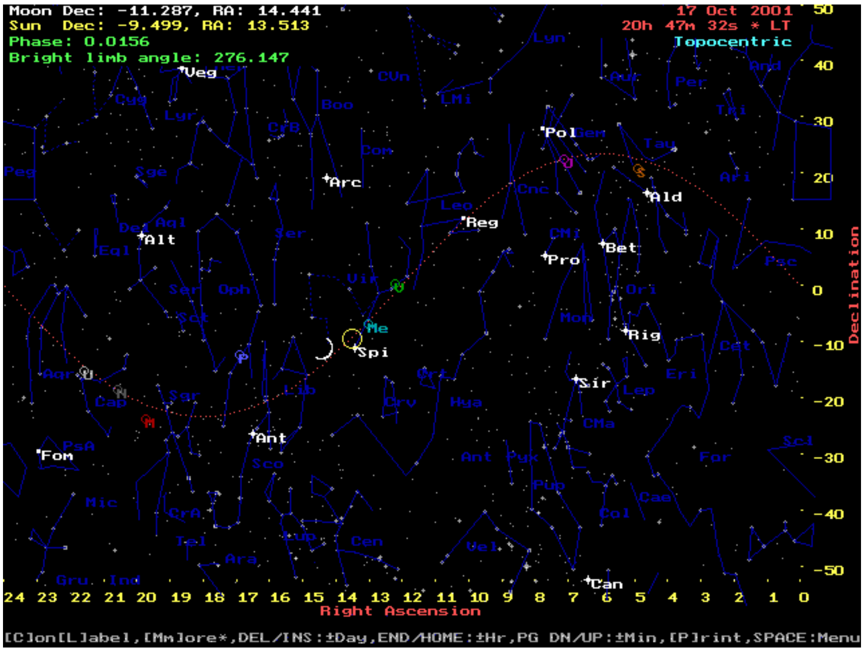
- Choose option 1 from Main Menu and enter the name and details of the location in question.
- Enter a date near the time of interest and obtain the date of the astronomical new moon (also known as date of conjunction).
- Go back to the Main Menu, choose option 1 again and enter this date.
- Go to screen 2 of 4 which shows the data at local sunset.
- The program will probably say that moon is 'Not visible' or 'Moon not new' ('Moon not new' means that the moon is over 7 days old and implies that it should be visible).
- Use the DEL/INS key to 'hunt' around this date until the earliest date when moon 'Should be visible' is obtained.
- Now go to screen 3 of 4 to obtain the data for when the sun is 5 degrees below the horizon i.e. the optimum time of sighting, azimuth etc.
- To get the information for the following month, go back to Screen 2 of 4 and press the '+' key to jump forward one lunar month. Again 'hunt' with the DEL/INS keys to obtain date of earliest sighting. Now go to screen 3 of 4 as before.

It may sound complicated but after a while you will find the procedure straightforward.

Alternatively, just go straight to screen 4 of 4 which performs the above steps automatically and shows the date when the previous new crescent would have been seen for the first time from you location (using the visibility criterion that you have chosen).

## 3.2 Option 2. Moon position on Starchart (Dec versus RA)

When this option is chosen, you will be required to enter the date and time. This option produces a star chart (a graph of Declination Angle versus Right Ascension) and plots the positions of the moon, sun and planets on it. The ecliptic is shown as a red line.



*Starchart: yellow circle=Sun; white disc/crescent= Moon, Me= Mercury, V=Venus, M=Mars, J=Jupiter, S=Saturn, U=Uranus, N=Neptune, P=Pluto; stars and constellations – see text.*

The positional data for the stars were obtained from the Yale Brightstar Database. The first magnitude stars are labelled using the first 3 letters of their common names. NB Pol is Pollux not Polaris (Pole Star)!

| COMMON NAME | MAGNITUDE |
|---|---|
| Sirius | -1.46 |
| Canopus | -0.72 |
| Alpha Centuri | -0.27 |
| Arcturus | -0.04 |
| Vega | 0.03 |
| Capella | 0.08 |
| Rigel | 0.12 |
| Procyon | 0.38 |
| Achernar | 0.46 |
| Betelgeuse | 0.50 |
| Hadar | 0.61 |
| Altair | 0.77 |
| Acrux | 0.83 |
| Aldebaran | 0.85 |
| Antares | 0.96 |
| Spica | 0.98 |
| Pollux | 1.14 |
| Fomalhaut | 1.16 |
| Deneb | 1.25 |
| Becrux | 1.25 |
| Regulus | 1.35 |

The planetary positions are also plotted and labelled:

| | |
|---|---|
| Me | Mercury |
| V | Venus |
| M | Mars |
| J | Jupiter |
| S | Saturn |
| U | Uranus |
| N | Neptune |
| P | Pluto [position not accurate for dates before 1890 CE] |

You can view and label the constellations. The constellation lines are based on information in Patrick Moore's Guinness Book of Astronomy (4th edition) (ref 34) which in turn refers to the Cambridge Sky Catalogues (1987). The 3 letter abbreviations for the constellations are as follows:

| | | |
|---|---|---|
| ANDROMEDA = And | ANTLIA = Ant | APUS = Aps |
| AQUARIUS = Aqr | AQUILA = Aql | ARA = Ara |
| ARIES = Ari | AURIGA = Aur | BOOTES = Boo |
| CAELUM = Cae | CAMELOPARDUS = Cam | CANCER = Cnc |
| CANES VENATICI CVn | CANIS MAJOR = CMa | CANIS MINOR = CMi |
| CAPRICORN = Cap | CARINA = Car | CASSIOPEIA = Cas |
| CENTAURUS = Cen | CEPHEUS = Cep | CETUS = Cet |
| CHAMAELEON = Cha | CIRCINUS = Cir | COLUMBA = Col |
| COMA BERENICES = Com | CORONA AUSTRALIS = CrA | CORONA BOREALIS = CrB |
| CORVUS = Crv | CRATER = Crt | CRUX AUSTRALIS = Cru |
| CYGNUS = Cyg | DELPHINUS = Del | DORADO = Dor |
| DRACO = Dra | EQUULEUS = Eql | ERIDANUS = Eri |
| FORNAX = For | GEMINI = Gem | GRUS = Gru |
| HERCULES = Her | HOROLOGIUM = Hor | HYDRA = Hya |
| HYDRUS = Hyi | INDUS = Ind | LACERTA = Lac |
| LEO = Leo | LEO MINOR = Lmi | LEPUS = Lep |
| LIBRA = Lib | LUPUS = Lup | LYNX = Lyn |
| LYRA = Lyr | MENSA = Men | MICROSCOPIUM = Mic |
| MONOCEROS = Mon | MUSCA AUSTRALIS = Mus | NORMA = Nor |
| OCTANS = Oct | OPHIUCHUS = Oph | ORION = Ori |
| PAVO = Pav | PEGASUS = Peg | PERSEUS = Per |
| PHOENIX = Phe | PICTOR = Pic | PISCES = Psc |

| | | |
|---|---|---|
| PISCIS AUSTRALIS = PsA | PUPPIS = Pup | PYXIS = Pyx |
| RETICULUM = Ret | SAGITTA = Sge | SAGITTARIUS = Sgr |
| SCORPIUS = Sco | SCULPTOR = Scl | SCUTUM = Sct |
| SERPENS = Ser | SEXTANS = Sxt | TAURAS = Tau |
| TELESCOPIUM = Tel | TRIANGULUM = Tri | TRIANGULUM AUSTRALE = TrA |
| TUCANA = Tuc | URSA MAJOR = Uma | URSA MINOR = UMi |
| VELA = Vel | VIRGO = Vir | VOLANS = Vol |
| VULPECULA = Vul | | |

The bright limb angle, phase, Right Ascension and Declination of the moon and Right Ascension and Declination of the sun are also depicted.

Once the starchart is drawn, the following keys apply:

| | |
|---|---|
| C: | Draw/remove major constellation lines |
| L: | Label/unlabel major constellations with standard 3 letter abbreviation |
| P: | Print screen to Epson/HP compatible printer |
| M/m: | Show more/less stars (i.e. change magnitude) |
| SPACE: | Return to main menu |

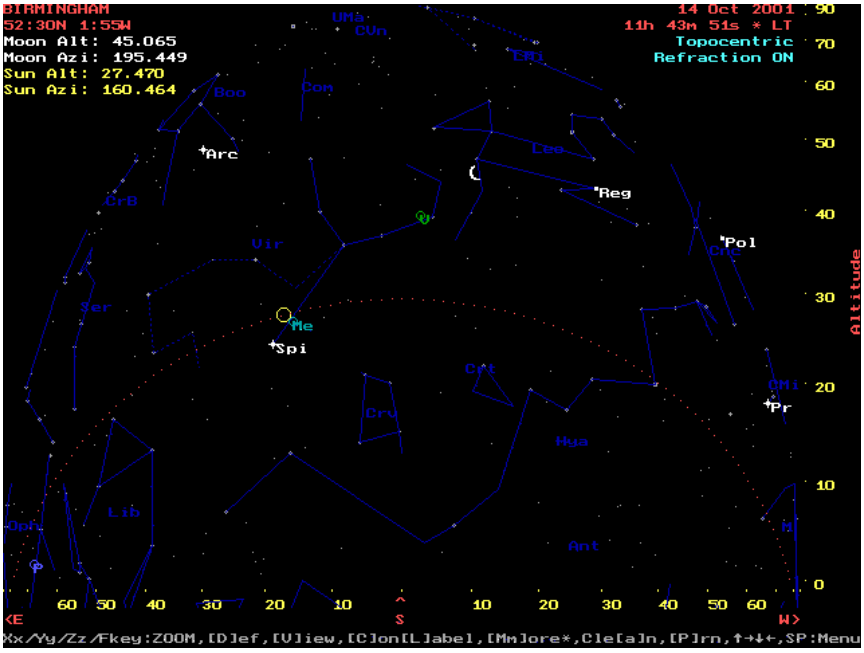
Also, as before...

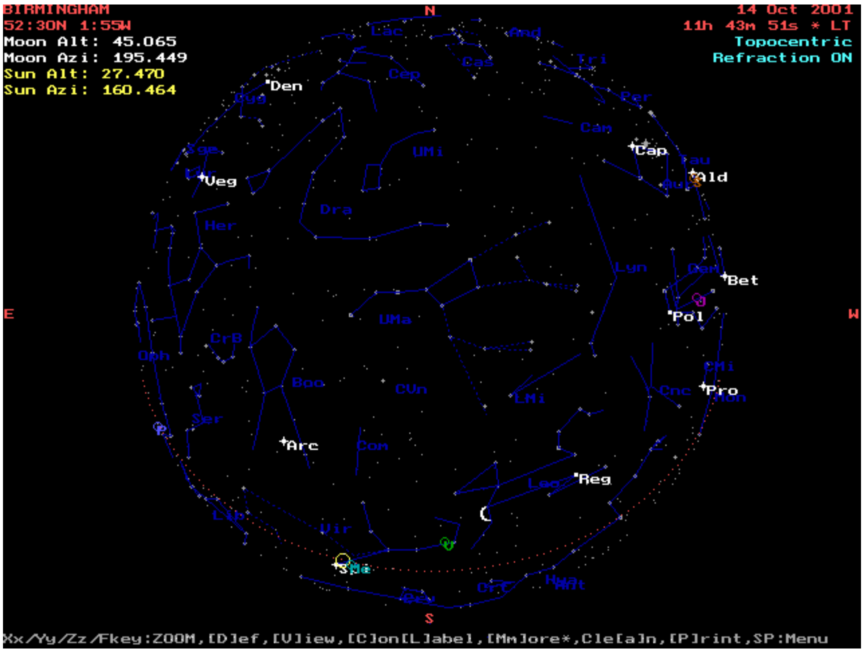
| | |
|---|---|
| +/- | increase/ decrease MONTH |
| DEL/INS | increase/ decrease DAY |
| END/HOME | increase/ decrease HOUR |
| PAGE DN/UP | increase/ decrease MINUTE |

## 3.3 Option 3. Simulation of Local Sky  (Alt versus Azi)

Enter the location and date/time data as usual. The maximum magnitude of stars to be displayed is also required. The star database in the program contains data for over 9000 stars down to magnitude seven (the lower the magnitude, the brighter the star). If you enter a high number for the maximum magnitude, the display will show more (and dimmer) stars but will take a long time to generate on a slower computer. On a slow machine it is better to view only the brighter stars (by specifying maximum magnitude as eg 2 or 3).

The program will now generate a simulation of the sky showing the position of the stars and planets. You can toggle between a 'horizon' view and a traditional 'circular' sky chart. The latter gives a view of the sky as it would appear if you were lying on your back with your head facing north and feet facing south:




*Sky simulation: horizon view (above), circular view (below); Yellow circle=Sun; white disc/crescent= Moon, Me= Mercury, V=Venus, M=Mars, J=Jupiter, S=Saturn, U=Uranus, N=Neptune, P=Pluto; stars & constellations – see text*

The positions of the moon and sun are drawn on this background of stars and planets. The moon is drawn in white showing the correct phase and orientation taking into account its bright limb angle and parallactic angle. The sun is represented by a yellow circle. A printout of the graphical screen can be made if an Epson dot matrix or HP Laserjet/Inkjet printer is connected.

Once the sky is drawn, the following keys apply:

| | |
|---|---|
| X/x, Y/y: | Zoom in/out in the X and Y axes respectively |
| Z/z: | Zoom in/out maintaining current aspect ratio |
| Function keys 1-10: 10 | Pre-set zooms (zoom factor 1.1 to 3) |
| D: | Set initial default zoom of 1 |
| Cursors: | Change direction of view (only in horizon view) |
| N,E,S,W | Change direction of view (only in horizon view) |
| P: | Print screen to Epson/HP compatible printer |
| C: | Draw/remove major constellation lines |

L: Label/unlabel major constellations with standard 3 letter abbreviation
A: Toggles between cleAn screen & labelled screen
M/m: Show more/less stars (i.e. change magnitude)
V: Toggle between horizon view and circular sky view
SPACE: Return to main menu

Other keys which apply but which are not shown at the bottom of the screen are the usual:

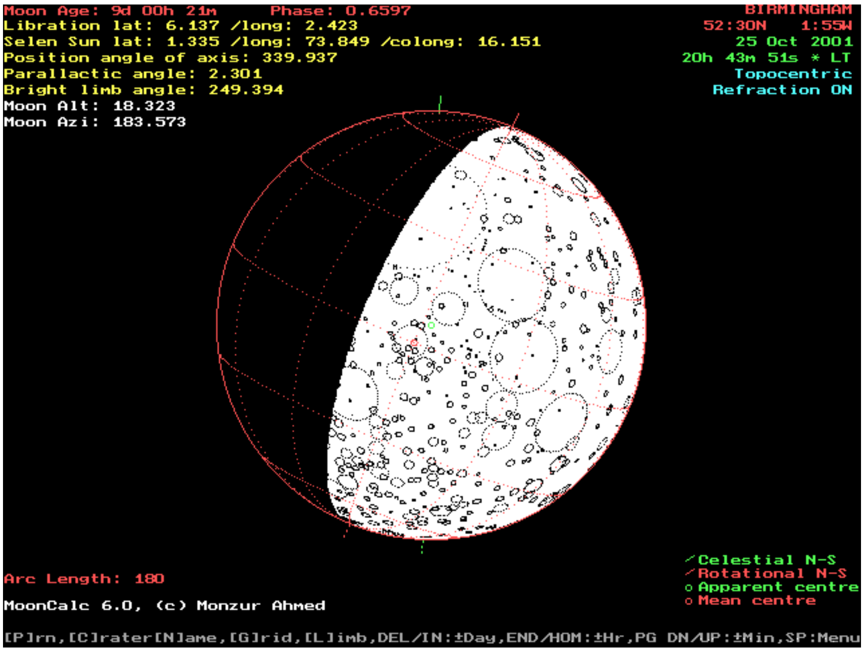
+/- increase/ decrease MONTH
DEL/INS increase/ decrease DAY
END/HOME increase/ decrease HOUR
PAGE DN/UP increase/ decrease MINUTE

We can 'see' the moon and sun setting or rising by increasing /decreasing the hour with END/HOME. We can zoom in and out of the central part of the sky using X/x, Y/y and Z/z. The function keys will produce images at preset zoom factors (Function key1=zoom factor 1.1, Function key 10= zoom factor 3).

## 3.4 Option 4. Close-up of Moon

As before, the place and date/time are first entered. A graphical representation of a close up of the moon is shown. The phase and orientation of the moon's limbs are depicted accurately.

The top left hand part of the screen also shows numeric values of phase, age, libration (latitude and longitude), position angle of axis, bright limb angle, parallactic angle, selenographic sun latitude, longitude and co-longitude, moon altitude and moon azimuth. The libration shown is the total (optical + physical) libration and is calculated using methods described by D.H. Eckhardt.




*Close up of moon: craters can be switched on/off with 'C' and labelled/ unlabelled with 'N'; grid can be switched on/off with 'G'; difference between apparent and mean centres reflects libration*

Some of the above values will change slightly depending on whether MoonCalc is set to 'geocentric' or 'topocentric' and also if refraction is on/off (see sections 3.10.11 and 3.10.12). Please note that values of certain physical parameters of the moon given in the printed Almanac are geocentric. In particular, geocentric and topocentric libration may differ by as much as 1 degree. Topocentric reduction in the values for libration and position angle of axis are made using differential corrections - equations in Explanatory Supplement to the Astronomical Ephemeris. See section 3.7 for more information on libration.

Again one can increase/decrease the month, day, hour or minute using the key combinations below and see the effect on the moon's appearance:

| | |
|---|---|
| +/- | increase/ decrease MONTH |
| DEL/INS | increase/ decrease DAY |
| END/HOME | increase/ decrease HOUR |
| PAGE DN/UP | increase/ decrease MINUTE |

This feature is especially useful for seeing how the orientation of the moon changes hour by hour.

Other keys which apply are:

'C': toggles between 'craters on' and 'craters off'. Switch on the craters feature if you have a fast machine (486DX or higher). When this feature is switched on, the craters and seas of the near side of the moon are depicted graphically taking libration into account.

'N': labels the larger craters/seas (remember 'N' for name)

'G': produces a latitude/longitude grid and shows the mean and apparent centres of the disc as well as the rotational and celestial axes.

'L': invokes 'limb shortening' i.e. for very thin crescents the tips of the crescent are not visible and so the crescent length is less than 180 degrees, sometimes considerably less. Pressing 'L' will not only shorten the crescent but will also display the approximate visible crescent length in degrees. MoonCalc uses algorithms developed from the data of Danjon (1932, 1936) and Schaefer (1991,ref 19) to shorten the crescent length.

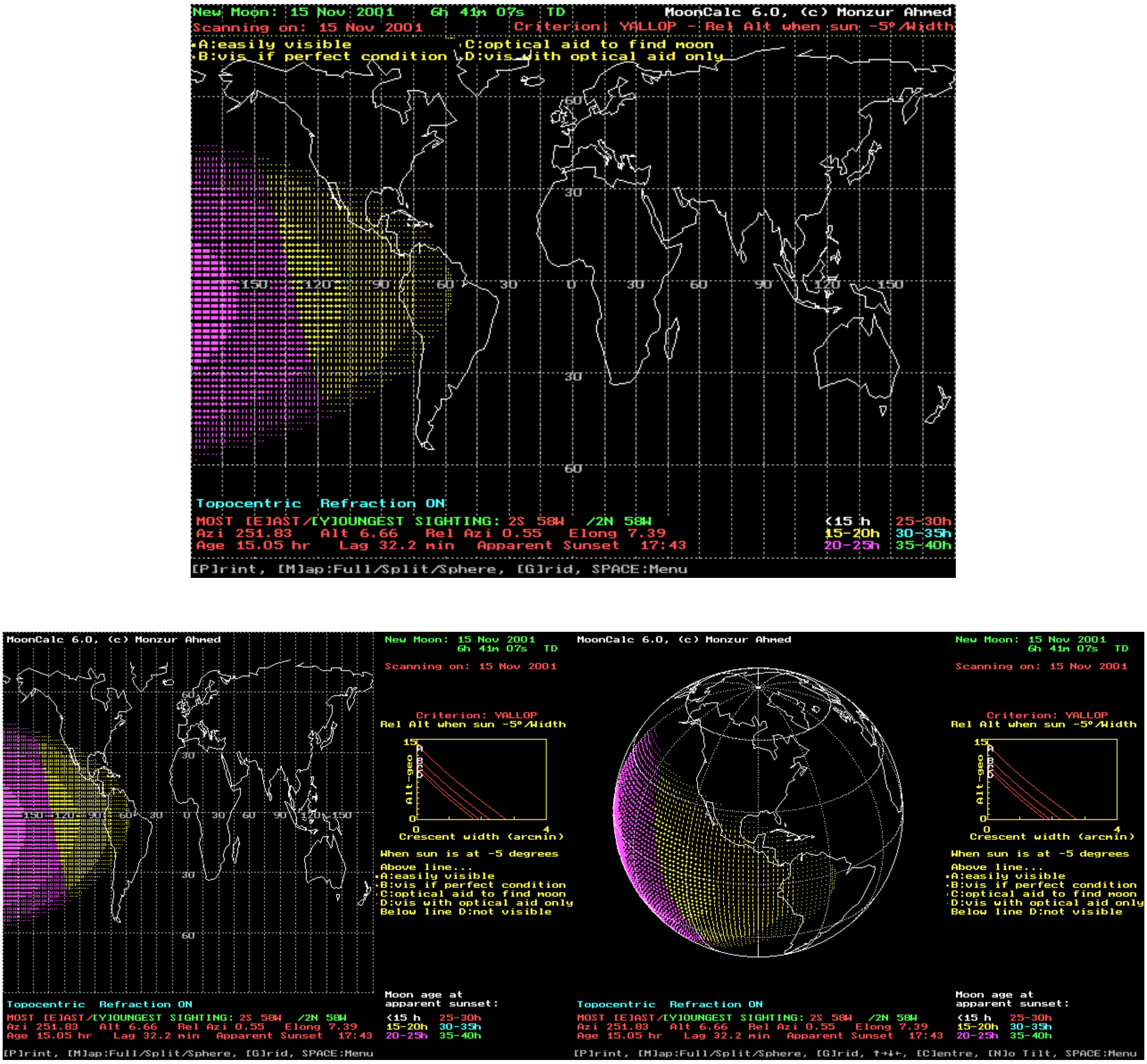
'P': a printout of the graphical screen can be made if an EPSON compatible or HP Laserjet/Inkjet printer is connected.

'SPACE': return to menu.

## 3.5 Option 5. First Crescent Sighting (Global Scan)

MoonCalc is able to predict the areas of the world where the young crescent moon is likely to be initially seen using one of several published/well known moon sighting criteria. The program will draw a world map and scan the world starting at longitude 180W and progress eastwards. The progress of the scan is indicated by a dotted yellow line near the top of the screen. The scan is performed in two passes (coarse scan first, then fine scan).

You can start scanning either on the day of conjunction or on the following day. At each longitude the program will search from a lower latitude (eg 60S) to a upper latitude (eg 60N). In other words, the world is divided into a fine grid and each intersection on the grid is examined to see if the new moon is visible at that location. If the minimum moon visibility criterion is satisfied by that location, then the location is marked with a coloured dot - the colour of the dot represents the age of the moon at local sunset (see lower right hand corner of the output screen for key to these colours). The map can be displayed in three ways:




*Global scan: standard flat map (top), split screen with flat map (left); split screen with spherical map (right). Toggle between the three by pressing 'M'*

At the end of the scan the program will display the location of the place where the moon will be first sighted (youngest sighting) as well as the most eastern location where the moon will be sighted (most easterly sighting). The location of the youngest sighting is usually slightly northwest or southwest of the most easterly point. The properties of the moon at the time of local sunset at the two points are shown at the bottom of the screen (use Y or E to toggle).
After the scan is complete the following keys apply:

| | |
|---|---|
| P: | printout of display |
| M: | change map layout (flat-full, flat-split, spherical-split) |
| Cursors: | used to spin spherical map |
| N: | remove tilt from spherical map (ie centre on 0 latitude) |
| C: | centre spherical map (ie centre on 0 longitude) |
| G: | show/hide latitude/longitude grid |
| Y: | show data for location of Youngest sighting. |
| E: | show data for most Easterly sighting. |
| SPACE: | return to menu |

The global scan is a *very* processor intensive procedure and may take a long time to complete on slower computers. You can exit at any time during the scan by pressing ESC. If during a scan, you think that the scan has already located all possible areas where the new moon is likely to be seen you can save time by terminating the scan early by pressing any key (except ESC or SPACE). It is inadvisable to terminate prematurely if you are using the RGO 67 criterion as the visibility zone for this criterion can be discontinuous. The scan can also be speeded up by making the initial scan grid less fine (see section 3.10.7 and 3.10.8).

3.5.1 Moon sighting criteria used in MoonCalc

*"The computation of the appearance of the new crescent is a very long and difficult procedure, the demonstration of which requires long calculations and many tables..."* Al-Biruni (973-1048 CE)

Since ancient times, astronomers have tried to predict the likelihood of seeing the new moon by defining minimum visibility criteria. MoonCalc currently supports 13 such criteria. The user can choose the moon visibility criterion to be used (see section 3.10.6). The following options exist:

- **Babylonian** **Age at sunset>24hrs & Lag>48 mins**

In ancient times, using observational data, the Babylonians developed a moon sighting criterion where the moon was likely to be visible when the sunset to moonset interval was >48mins (ie the difference in RA of sun and RA of moon at sunset was >12 degrees) and moon age at sunset was >24 hours. Although generally attributed to the Babylonians (eg ref 10), recent studies suggest that this criterion may actually have been developed by the ancient Indians.

- **Ibn Tariq** **[Alt, Lag]**

Muslim astronomers extensively investigated the problems of moon sighting especially in the 8th-10th century CE. They developed visibility criteria and created tables for calculations.

MoonCalc currently supports Ibn Tariq's criterion which depends on moon altitude at sunset and moonset lag. It is hoped that future versions of MoonCalc will support other criteria from this era, eg the criteria of Al-Kwarizmi, Al-Batani, Habash and others.

- **Fotheringham** **[Alt, Rel Azi]**

In 1910 Fotheringham developed a moon visibility criterion based mainly on the extensive observational data of Schmidt made at Athens over a period of 20 years (ref 6). During this time Schmidt had documented the sightability or unsightability of many moons. Using Schmidt's data, Fotheringham plotted a scatter diagram of moon's altitude at geometric sunset versus the difference in azimuth (relative azimuth) between the sun and the moon at sunset. A curve was drawn separating the 'visible' moons from the 'unsighted' moons. This curve was then used to predict the likelihood of sighting young moons - if a new moon's alt/rel azi falls above the curve than it should be sightable, if it falls below the curve it should not be sightable.

- **Maunder** **[Alt, Rel Azi]**

In 1911, Maunder again used Schmidt's data together with a few more observations (ref 7). He drew the curve lower than Fotheringham.

- **Indian/Schoch** **[Alt, Rel Azi]**

The Indian Astronomical Ephemeris used a slightly modified version of the above two criteria, drawing the line slightly lower than Maunder (ref 8). The Indian criterion was initially developed by Carl Schoch (ref 9).

- **Bruin** **[Alt, Crescent width]**

In 1977 F. Bruin published details of a theoretical moon sighting criterion based on crescent width and sun/moon altitude (ref 10). In its original form, the criterion was represented by a family of V shaped curves on a graph of relative altitude (h+s) versus solar depression (s). Each curve in the family represented a certain crescent width. Bruin used 0.5 minutes as the limiting crescent width. The curves were meant to indicate the solar depression at which the crescent would become visible and also the duration of visibility. The criterion was subsequently criticised for making certain erroneous assumptions.

MoonCalc uses a slightly modified version of the Bruin criterion with limiting crescent width=0.25 minutes as suggested by Ilyas (1984). The criterion as implemented in MoonCalc has been simplified so that it now indicates *if* the crescent is visible on a particular evening (and not the duration of visibility).

- **Ilyas_A [Alt, Elong]**

Ilyas has written extensively on moon sighting and lunar calendars (eg ref 11,12,13 17 and 18). MoonCalc supports three of Ilyas' best known sighting criteria. The first criterion depends on the 'moon's relative altitude at sunset' and the 'sun-moon elongation at sunset' (ie angular separation between the sun and the moon). Again a curve based on observational data was drawn on a graph of moon's elative altitude at sunset versus sun-moon elongation at sunset. If the properties of a crescent lie above the curve then the crescent should be visible and vice versa.

- **Ilyas_B/modified Babylonian [Lag, Latitude]**

Ilyas' second criterion is a modification of the ancient Babylonian system of moonset lag times. However Ilyas compensates for latitude (eg at latitude 0 deg: lag 41 min; 30 deg:46 mins, 40 deg:49 mins, 50 deg: 55mins).

- **Ilyas_C [Alt, Rel Azi]**

Ilyas' third criterion, described in 1988, is a slight modification of Ilyas_A and depends on the moon's relative altitude at sunset and the difference in azimuth between the sun and moon at sunset.

- **RGO 67 [Alt, Elong]**

The Royal Greenwich Observatory (which sadly closed recently) produced a series of information sheets which tabulated predicted first moon sightings (ref 15). The calculations are based on the rule that the best time and place for making the earliest sightings are when the moon is vertically above the sun at sunset so that their azimuths are equal (ie relative azimuth at sunset=0) and where the apparent altitude of the moon at sunset is 10 degrees. If the sky is clear and the horizon is flat, sighting should be possible just before the sun reaches a geocentric altitude of -5 degrees. The criterion as implemented in MoonCalc is useful for finding the earliest location where the new moon is likely to be sighted. On a global scan, the criterion does *not* show all areas west of the 'earliest point' where the crescent will be seen.

- **South African Astronomical Observatory (SAAO) [Alt, Rel Azi]**

This is a sighting criterion proposed by Drs. John Caldwell and David Laney of the South African Astronomical Observatory (ref 20). The criterion was based on published crescent sightings together with a few local sightings from Signal Hill. The criterion depends on 'topocentric moon altitude (to lower limb) at apparent sunset' and 'difference in azimuth at sunset'. Two lines are drawn on a graph of altitude versus relative azimuth. The sightability of a crescent is 'possible' if above upper line, 'improbable' if between the two line or 'impossible' if below the lower line.

- **Shaukat [Alt, Crescent width]**

This criterion, proposed by Khalid Shaukat and the Committee for Crescent Observation, New York, depends on the 'topocentric altitude of the moon (to the lower limb) at sunset' and the 'calculated crescent width at sunset'. The altitude must be >3.4 degrees at sunset and (alt/12.7) + (crescent width in arcmin /1.2)>1. The crescent width is calculated in a slightly non-standard way. The criterion has undergone successive refinements based on prospectively collected observation data.

- **Yallop 1997/8 [Rel Alt, Crescent Width]**

This criterion was developed from the Indian and Bruin criteria by Bernard Yallop (formerly of the Royal Greenwich Observatory, Cambridge, UK). It takes into account information from 295 published moon (non)sightings compiled by Schaefer and Doggett. The criterion depends on a parameter called 'q' which is derived from the relative geocentric altitude of the moon (ARCV) and topocentric crescent width. This is the default criterion used in MoonCalc.
In the original technical note by Yallop (ref 24), q was derived at 'best time' (ie sunset + (4/9)* moonset lag). However, it is not always practical to apply the criterion at 'best time' and so MoonCalc allows the criterion to be applied at sunset or when the sun is at -5 degrees as well as at 'best time'.

The value of q is stratified to give 6 types of predictions:

A: easily visible
B: visible when atmospheric conditions are perfect
C: may need optical aid to find crescent
D: visible with optical aid only
E: not visible even with optical aids
F: outside Danjon limit

Note that applying the criterion at sunset makes the visibility predictions slightly more pessimistic compared to 'best time', and global visibility zones are west shifted by about 5 degrees of longitude.

- **Schaefer 1988** **Not Yet Implemented**

B.E. Schaefer has developed a complex theoretical sighting criterion based on the idea of Bruin. This criterion apparently takes into account atmospheric haziness, aerosol scattering, Rayleigh scattering, ozone absorption etc (see refs 16,21 and 22). Despite several publications, this criterion has not yet been documented in sufficient detail to implement in MoonCalc.

## 3.6 Option 6. Hijri Calendar Tabulation

MoonCalc can tabulate Hijri calendars based on predicted crescent visibility. Choosing option 6 from the main menu leads to the following Menu:

```
IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
I  Moon Calculator                Version 6.0  I
I  By Dr. Monzur Ahmed      (c) May 93/Oct 01  I
I                                              I
I----------------------------------------------I
I    H I J R I   C A L E N D A R   M E N U     I
I----------------------------------------------I
I                                              I
I                                              I
I          1. Local Calendar                   I
I          2. Trizonal Calendar (text mode)    I
I          3. Trizonal Calendar (map mode)     I
I          X. Exit to Main Menu                I
I                                              I
I                                              I
I                                              I
I                                              I
I                                              I
I                                              I
I                                              I
I    Use cursor keys or 1-3 to make choice     I
IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
```

### 3.6.1 Local Calendar

On choosing this option, we are asked to enter a location and date. The program then produces a table showing a local Hijri calendar based on predicted crescent visibility specific for the chosen location; eg for Birmingham, UK:

```
IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
I BIRMINGHAM 52:30N 1:55W TZ:0.0 Ht:236m                                       I
I LOCAL HIJRI CALENDAR BASED ON PREDICTED CRESCENT VISIBILITY                  I
I                                                                              I
I Hijri month               Greogorian date   Hijri Day   Islamic Lunation     I
I                                                                              I
I 1 Rajab 1422 AH             19 Sep  2001      503733      17059              I
I 1 Shaban 1422 AH            19 Oct  2001      503763      17060              I
I 1 Ramadhan 1422 AH          17 Nov  2001      503792      17061              I
I 1 Shawwal 1422 AH           17 Dec  2001      503822      17062              I
I 1 Zul-Qida 1422 AH          16 Jan  2002      503852      17063              I
I 1 Zul-Hijja 1422 AH         14 Feb  2002      503881      17064              I
I 1 Muharram 1423 AH          16 Mar  2002      503911      17065              I
I 1 Safar 1423 AH             15 Apr  2002      503941      17066              I
I 1 Rabi Al-Awal 1423 AH      14 May  2002      503970      17067              I
I 1 Rabi Al-Thani 1423 AH     13 June 2002      504000      17068              I
I 1 Jumad Al-Ula 1423 AH      12 July 2002      504029      17069              I
I 1 Jumad Al-Thani 1423 AH    10 Aug  2002      504058      17070              I
I                                                                              I
I 1st day of Hijri months end at sunset on Gregorian dates shown.              I
I Criterion: Yallop/BT [A or B]                                                I
I                                                                              I
I                                                                              I
I [M]ore, Space: Menu                Data from MoonCalc 6.0, (c) Monzur Ahmed I
IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
```

In this example, Yallop's criterion (applied at "Best Time") is being used to predict crescent visibility. You can choose any of the supported criteria to predict crescent visibility - see section 3.10.6. The Gregorian dates corresponding to the start of the Hijri months are shown. In addition the Hijri day number and Islamic lunation number are listed. In the above example, 1st Rajab 1422 AH (after Hijra) occurs on 19th September 2001, the crescent being sightable in Birmingham on the evening of 18th September 2001.

<u>3.6.2 Trizonal Calendar (text mode)</u>

For practical purposes, the world can be divided into 3 main zones with a Hijri calendar for each of the 3 zones. The 3 zones are:

1. Zone A (west)- North, Central and South America, Canada etc
2. Zone B (central) - Europe, Africa, Middle East etc
3. Zone C (east)- India, Pakistan, Bangladesh, Malaysia, China, Indonesia, Australia etc

```
IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
I TRIZONAL HIJRI CALENDAR BASED ON PREDICTED CRESCENT VISIBILITY               I
I                                                                              I
I Hijri month                     Zone A           Zone B          Zone C      I
I                                 (West)         (Central)         (East)      I
I                                                                              I
I 1 Rajab 1422 AH               18 Sep  2001    19 Sep  2001    19 Sep  2001   I
I 1 Shaban 1422 AH              18 Oct  2001    18 Oct  2001    19 Oct  2001   I
I 1 Ramadhan 1422 AH            16 Nov  2001    17 Nov  2001    17 Nov  2001   I
I 1 Shawwal 1422 AH             16 Dec  2001    17 Dec  2001    17 Dec  2001   I
I 1 Zul-Qida 1422 AH            15 Jan  2002    15 Jan  2002    15 Jan  2002   I
I 1 Zul-Hijja 1422 AH           14 Feb  2002    14 Feb  2002    14 Feb  2002   I
I 1 Muharram 1423 AH            15 Mar  2002    16 Mar  2002    16 Mar  2002   I
I 1 Safar 1423 AH               14 Apr  2002    14 Apr  2002    15 Apr  2002   I
I 1 Rabi Al-Awal 1423 AH        14 May  2002    14 May  2002    14 May  2002   I
I 1 Rabi Al-Thani 1423 AH       12 June 2002    13 June 2002    13 June 2002   I
I 1 Jumad Al-Ula 1423 AH        11 July 2002    12 July 2002    12 July 2002   I
I 1 Jumad Al-Thani 1423 AH      10 Aug  2002    10 Aug  2002    10 Aug  2002   I
I                                                                              I
I 1st day of Hijri months end at sunset on Gregorian dates shown.              I
I Criterion: Yallop/BT [A or B]                                                I
I                                                                              I
I                                                                              I
I [M]ore, Space: Menu                Data from MoonCalc 6.0, (c) Monzur Ahmed I
IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
```

As you can see from the above example, the dates for the 3 zones vary slightly. This is because the Hijri calendar is based on crescent visibility and generally the new crescent is not seen from all locations on the same evening. Usually it takes at least two days for the crescent to be visible from all regions.

In this example, 1st Rajab 1422 AH occurs on 18th September 2001 for Zone A and 19th Sept for Zones B and C. The implication is that the crescent was sightable after sunset on the evening of 17th September in Zone A and 18th Sept in Zones B and C.

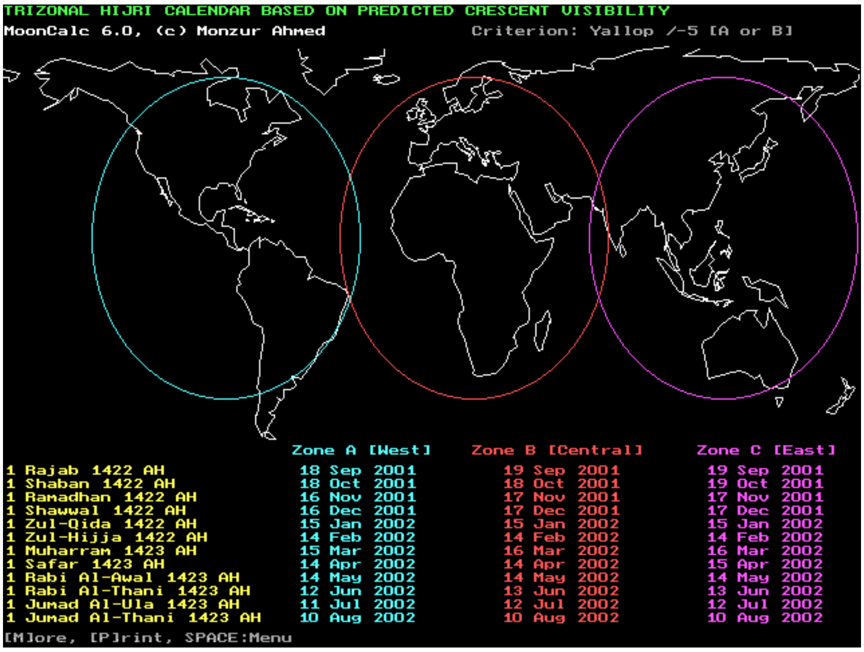
The trizonal calendar is an approximation. All countries within a zone will not necessarily see the new crescent on the same day but the crescent will be visible from at least a part of the zone on the day indicated.

Technical note: MoonCalc chooses a "sampling point" in the mid-western region of each of the three zones and calculates crescent visibility for that point. If the new crescent is visible at this point on date X, then this date is applied to the entire zone. The co-ordinates of the three "sampling points" are:

Zone A- latitude 20N, longitude 150W
Zone B- latitude 20N, longitude 15W
Zone C- latitude 0, longitude 100E

3.6.3 Trizonal Calendar (map mode)

The calendar generated is the same as in 3.6.2 but the output is in graphic rather then text format. A map of the world is shown with the three zones marked out approximately.

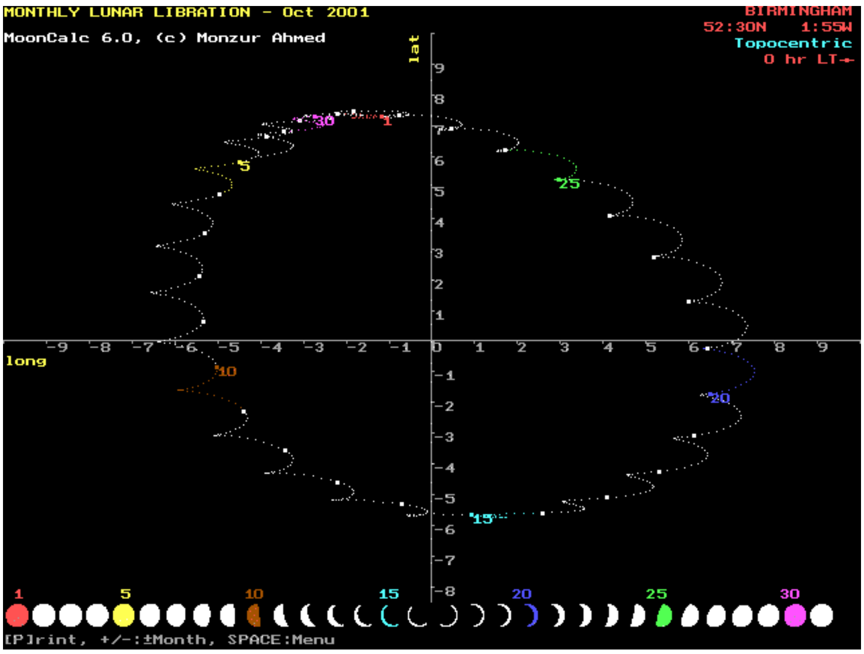


*Tri-zonal calendar – the 3 zones are indicated by the coloured ellipses*

## 3.7 Option 7. Libration Graph

Optical libration is the apparent oscillations of the moon due to the variations in the geometric position of the Earth relative to the lunar surface during the course of the orbital motion of the moon. Physical libration is the actual rotational motion of the moon about its mean rotation. Physical libration is much smaller than optical libration and can never be larger than 0.04 degrees in both latitude and longitude.

This option draws a graph showing TOTAL libration in latitude versus TOTAL libration in longitude for a whole month. The user can choose either topocentric or geocentric libration (see 3.10.11).



*Libration graph: the dates are labelled on the graph at intervals of 5 days. The square points on the graph represent midnight. At the bottom the screen, the corresponding daily phases of the moon for the month are drawn.*

The libration graph is useful for seeing at a glance the days of maximum libration in a particular month thus facilitating observation of "far-side" lunar features.

## 3.8 Option 8. Eclipses

*"To witness a total eclipse of the Sun is a privilege that comes to but few people. Once seen, however, it is a phenomenon never to be forgotten.... There is something in it all that affects even the strongest nerves and it is almost with a sigh of relief that we hail the return of the friendly Sun."*
Isabel M. Lewis, 1924, A Handbook of Solar Eclipses

Version 5 of MoonCalc (and higher) provides data on lunar and solar eclipses. First, enter the year in question. MoonCalc will then list all the lunar and solar eclipses in that year, together with the characteristics of the respective eclipses.

```
IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
IYear: 2001                                                                    I
I                                                                              I
ISolar Eclipses:                                                               I
I Max eclipse: 21 June 2001   12:05 TD   central, total                        I
I Max eclipse: 14 Dec  2001   20:53 TD   central, annular                      I
I                                                                              I
ILunar Eclipses:                                                               I
I Max eclipse: 9  Jan  2001   20:22 TD   umbral, mag 1.186                     I
I Max eclipse: 5  July 2001   14:57 TD   umbral, mag 0.492                     I
I Max eclipse: 30 Dec  2001   10:30 TD   penumbral, mag 0.884                  I
I                                                                              I
I                                                                              I
I                                                                              I
I                                                                              I
I                                                                              I
I                                                                              I
I                                                                              I
I                                                                              I
I                                                                              I
I                                                                              I
I                                     Data from MoonCalc 6.0, (c) Monzur Ahmed I
I------------------------------------------------------------------------------I
IENTER:Another year  SPACE:Main Menu                                           I
IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
```

I should like to develop this aspect of MoonCalc further in future versions, eg have world maps showing zones of totality for solar eclipses, show graphic simulations of solar and lunar eclipses etc.

## 3.9 Option 9. Add/ Delete/ Change/ View Atlas Data

The program has a built in database which can store data for up to 1000 cities. The program is shipped with over 100 cities already on the database. The following pieces of information are stored for each city:

- Name of city
- Country (optional)
- Latitude
- Longitude
- Time Zone
- Whether influenced by Summer Time
- Height above sea level in metres

Choosing this option allows us to make alterations to the ATLAS DATABASE:

```
IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
I  Moon Calculator                 Version 6.0  I
I  By Dr. Monzur Ahmed      (c) May 93/Oct 01  I
I                                              I
I----------------------------------------------I
I           A T L A S   D A T A B A S E        I
I----------------------------------------------I
I                                              I
I                                              I
I               1. Add data                    I
I               2. Delete data                 I
I               3. Change data                 I
I               4. View data                   I
I               X. Exit to Main Menu           I
I                                              I
I                                              I
I                                              I
I                                              I
I                                              I
I                                              I
I    Use cursor keys or 1-4 to make choice     I
IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
```

It is best to add a town to the atlas before using it so as to save time inputting latitude/longitude data.

### 3.9.1. Add data

Follow the prompts and enter the name of the new location, the country optional), the latitude, longitude and time zone. Enter the height of the location above sea level (zero if you do not know) and also *whether* summer time (British Summer Time/ Daylight Saving Time) should operate. (Note that the rules determining *when* Summer Time starts and ends can be altered using 'Option 10. Change Options' from the Main Menu, see section 3.10.3)

Once the location has been entered into the database, it will be saved and the name of the location will appear in the scrolling window when option 1,2,3 or 4 are chosen from the Main Menu.

### 3.9.2. Delete data

Simply type in the name of a location which already exists in the database to remove it from the database. Make sure that the spelling is correct (although the case does not matter).

### 3.9.3. Change data

Type in the name of a location which already exists in the database and follow the prompts to alter its properties.

### 3.9.4. View data

This generates a table showing all the locations stored in the database in alphabetical order. Use Page Up/Down to browse.

## 3.10 Option 10. Change Options

Choosing this item from the main menu takes us to the OPTIONS MENU:

```
IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
I  Moon Calculator                Version 6.0  I
I  By Dr. Monzur Ahmed      (c) May 93/Aug 01  I
I                                              I
I----------------------------------------------I
I            O P T I O N S    M E N U          I
I----------------------------------------------I
I                                              I
I                                              I
I         1. Basic Options                     I
I         2. Advanced Options                  I
I         X. Exit to Main Menu                 I
I                                              I
I                                              I
I                                              I
I                                              I
I                                              I
I                                              I
I                                              I
I                                              I
I    Use cursor keys or 1-2 to make choice     I
IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
```

**Basic Options**

If we choose BASIC OPTIONS, the following screen is displayed:

```
IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
I                                                                    I
I                      CURRENT DEFAULT SETTINGS                      I
I                                                                    I
I Default City: BIRMINGHAM                                           I
I                                                                    I
I Mode of time entry/display: Local Civil Time (LT)                  I
I                                                                    I
I Summer Time, if present, begins on fourth Sunday of month 3        I
I                          ends on fourth Sunday of month 10         I
I                                                                    I
I Monitor Type: Colour                                               I
I                                                                    I
I Map Type: Full screen flat map                                     I
I                                                                    I
I                                                                    I
I                                                                    I
I  Press SPACE to make changes, D for original defaults, ESC to exit I
IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
```

Pressing 'D' will reset to original factory set defaults. Pressing the Space Bar allows the user to change the following values which are stored as defaults and remembered when the program is next run:

3.10.1 Default City- usually set to the users home town.

3.10.2 Mode of time entry- Can be set to Local Civil Time (LT) or Universal Time (UT). The former option is recommended so that the time that is displayed applies to the user's location.

3.10.3 Start and End of Summer Time/Daylight Saving Time

The rules for the start and finish of Summer Time or Daylight Saving Time (DST) vary from country to country. For example, in 1986 the effective periods for DST for various countries were as follows:

| COUNTRY | Effective DST period (dates inclusive) | | |
|---|---|---|---|
| AUSTRALIA | 26 OCT 86 | - | 28 FEB 86 |
| CANADA | 27 APR 86 | - | 25 OCT 86 |
| FRANCE | 30 MAR 86 | - | 27 SEP 86 |
| IRAQ | 01 APR 86 | - | 30 SEP 86 |
| ITALY | 30 MAR 86 | - | 27 SEP 86 |
| JORDAN | 04 APR 86 | - | 02 OCT 86 |
| SPAIN | 30 MAR 86 | - | 27 SEP 86 |
| SYRIA | 16 FEB 86 | - | 18 OCT 86 |
| TURKEY | 30 MAR 86 | - | 27 SEP 86 |
| USA | 27 APR 86 | - | 25 OCT 86 |
| UK | 30 MAR 86 | - | 25 OCT 86 |

(NB: for some countries, eg USA, rules may have changed since 1986!)

During DST, one hour (in most countries) is added to the standard time. In many countries there are general rules for the start and end of DST. For example, in the UK, DST (British Summer Time) usually starts on the fourth Sunday of March and ends on the fourth Sunday of October. Similarly, in most areas of the USA, DST starts on the first Sunday of April and ends on the last Sunday of October.

The DST handling of the program has been designed to be flexible enough to cater for most countries of the world. The start/end of DST can be set either as an **absolute** date e.g. 1st May or in a **relative** way e.g. fourth Sunday of March.

Essentially you have to answer 3 questions (following the prompts) to set the start or end of DST:

Q1. The month when DST starts or ends.

Q2. The day on which DST starts or ends.
- for absolute date, choose 'Specific date' for this question.
- for relative date, choose a day name e.g. 'Sunday'

Q3. The position of the day in the month.
- for absolute date, enter the date when you want DST to start/end.
- for relative date, enter the position of the day in the month i.e. first, second, third, fourth or last. For example if you want DST to start on the last Sunday of the chosen month, enter 'last' or if you want DST to start on the fourth Sunday, enter 'fourth'.

Example 1. If you want DST to start on 1st April, the three questions should be answered as follows:
Q1. 4
Q2. Specific date
Q3. 1

Example 2. If you want DST to start on the last Sunday of April, the three questions should be answered as follows:
Q1. 4
Q2. Sunday
Q3. last

The program ships with default start/end of DST valid for the UK i.e. DST starts on the fourth Sunday of March and ends on fourth Sunday of October.

If the Summer Time/DST rules are different for your location then you must alter the rules using this option. If you specify that Summer Time/DST does not apply for your location (when you enter the location into the database) then these rules will be ignored for that location.

3.10.4 Monitor Type: Colour or Black & White

3.10.5 Map Type You can choose the type of world map that will be displayed during a global scan when the program first runs:

1. Full screen flat map.
2. Split screen flat map showing extra information about the sighting criterion being used.
3. Split screen spherical map showing extra information about the sighting criterion being used.

**Advanced Options**

If you choose ADVANCED OPTIONS from the OPTIONS MENU, the following screen, or one similar to it, will appear:

```
IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
I                                                                    I
I                  ADVANCED SETTINGS FOR POWER USERS                 I
I      ONLY MAKE CHANGES IF YOU KNOW EXACTLY WHAT YOU ARE DOING!     I
I                                                                    I
I Visibility Criterion:  8 (Ilyas_C...........[Alt, Rel Azi])        I
I                                                                    I
I During scan, interval between longitudes:  2 deg                   I
I During scan, interval between latitudes:   2 deg                   I
I During scan, lower limit of latitude:     -60 deg                  I
I During scan, upper limit of latitude:      60 deg                  I
I                                                                    I
I [T]opocentric or [G]eocentric: T                                   I
I Correction for Refraction : Yes                                    I
I [A]pparent or [G]eometric sunrise/set: A                           I
I Atmospheric Temperature: 25 Celsius                                I
I Atmospheric Pressure: 1010 millibars                               I
I                                                                    I
I                                                                    I
I Press SPACE to make changes, D for original defaults, ESC to exit  I
IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
```

**WARNING!**

ONLY MAKE CHANGES TO THESE SETTINGS IF YOU ARE SURE THAT YOU KNOW WHAT YOU ARE DOING. OTHERWISE THE PROGRAM MAY PRODUCE SPURIOUS OR MISLEADING RESULTS.

Pressing 'D' will reset to factory set defaults. To make changes, press the SPACE BAR.

3.10.6 Visibility Criterion

The following screen will appear:

```
WHICH NEW MOON VISIBILITY CRITERION DO YOU WANT TO USE?

 0. Babylonian...................Age>24 hrs & Lag>48 mins
 1. Ibn Tariq....................[Alt, Lag]
 2. Fotheringham.................[Alt, Rel Azi]
 3. Maunder......................[Alt, Rel Azi]
 4. Indian/Schoch................[Alt, Rel Azi]
 5. Bruin........................[Alt, Crescent Width]
 6. Ilyas_A......................[Alt, Elong]
 7. Ilyas_B......................[Lag, Latitude]
 8. Ilyas_C......................[Alt, Rel Azi]
 9. RGO 67.......................[Alt, (Rel Azi)]
10. SAAO.........................[Alt, Rel Azi]
11. Shaukat......................[Alt, Crescent Width]
12. Yallop 1997/8................[Rel Alt, Crescent Width]

The current choice is 12
Press ENTER to accept or type in new default (0-12):
```

Choose the criterion that you wish to use (option 12, Yallop is the default used in the program). See section 3.5.1 for further information on each of these criteria.

If criterion number 9 (RGO 67) is chosen, then 2 further choices are provided:

- Minimum moon altitude at apparent sunset

Generally this should be 10 degrees in line with the RGO recommendations. However the calculated elongation of the world record moon sighting was 8.1 degrees (ref 14). The user is allowed to enter a value in the range 0-25 degrees.

- Maximum relative azimuth at sunset

According to RGO sheet 67 the place/time of earliest moon sighting occurs when the new moon and sun have the same azimuth at sunset ie relative azimuth is zero. When scanning the globe in steps of, say, one or two degrees a relative azimuth of zero is too strict. The program allows the user to 'loosen' the criterion a little by defining the maximum relative azimuth at sunset which can be taken to be zero. (Range allowed 0.001-30 degrees, default: 0.2 degrees, recommended: 0.1-0.5 degrees).

3.10.7 Interval between longitudes

We can define the fineness of the initial grid used for scanning the globe for new moon visibility (option 5 from the main menu). The finer the grid the longer it will take to complete the scan. This option allows you to set the interval in degrees between successive longitudes during the first, coarse scan. Range allowed (1-5 degrees). Use 1 degree if you have a fast computer (486DX or Pentium). Use higher values if you have a slower computer.

3.10.8 Interval between latitudes

This option defines the interval between successive latitudes during the first scan of the globe. The same comments as for 3.10.7 apply.

3.10.9 Lower limit of latitude

To save time you can define the upper and lower limits of latitude for the global scan. Usually a lower limit of -60 degrees (ie 60S) and an upper limit of 60 degrees (60N) are optimal. Range allowed for lower limit -30 to -90 degrees; default -60 degrees.

#### 3.10.10 Upper limit of latitude

See section 3.10.9. Range allowed for upper limit 30-90 degrees; default 60 degrees.

#### 3.10.11 Topocentric or Geocentric

Topocentric = as seen from the observer's place on surface of earth.
Geocentric = as seen from centre of the earth.
For actual moonsighting, it is usual to choose topocentric.
The *displayed* altitudes are always measured to the centre of the moon/sun regardless of topocentric/geocentric setting.

#### 3.10.12 Correction for refraction

Choose "Yes" if you want to compensate for atmospheric refraction.

#### 3.10.13 Apparent or Geometric sunset

Apparent sunset: when the upper limb of the sun is on the horizon taking into account refraction and parallax.
Geometric sunset: when the centre of the sun is on the horizon NOT taking into account refraction or parallax.

Generally this setting should be left on 'Apparent sunset' since this is the "usual" definition of sunset used in civil life.

For expert users: if you want to calculate such values as ARCV (arc of vision), DAZ (difference in azimuth) and ARCL (arc of light) as used in various moon sighting criteria, then set sunset to 'Geometric', Topocentric/Geocentric to 'Geocentric' and Refraction to 'OFF'.... then:

-relative altitude at sunset = ARCV
-relative azimuth at sunset = DAZ
-elongation at sunset = ARCL

#### 3.10.14 Atmospheric Temperature

The value will effect the internal calculation of refraction. Usually this should be set in the range 10-25 degrees Celsius.

#### 3.10.15 Atmospheric Pressure

The value will affect the internal calculation of refraction. Usually this should be set to 1010 millibars.

## 4. Future Developments

This is the third full release of MoonCalc. However, the program remains in a constant state of development. Please send your suggestions/comments, bug report etc to me either by snail mail or by email (see start of document for addresses).

There are many ideas in the pipeline to enhance MoonCalc. However the constraints of programming in DOS are becoming rather restrictive. I am still working on a Windows version of the program. Maybe, one day I may write a Java version.

At present, my primary concern is to remove any bugs from the data generating engine. As it stands, the program produces reliable data which is compatible with other planetarium type programs and sources.

Generally, the algorithms used in the program are very accurate (based on routines in refs 2 and 4 together with several other sources) and are probably more accurate than is actually needed by most users.

## 5. Acknowledgements

I should like to thank the many people who helped in the development and testing of this program over the past 8 years. In particular, I should like to thank Shakoor Chughtai (UK) for his helpful comments and extensive error testing in early versions of the program. I am indebted to Omar Afzal (Cornell University, USA) for providing me with certain difficult to locate reference materials. My thanks to Bernard Yallop (formerly of the Royal Greenwich Observatory, UK) for testing MoonCalc and providing friendly advice and stimulating discussions.

I am grateful to the many, many people who made useful comments on the earlier releases of MoonCalc including Rashid Motala, Yusuf Essack, Yaakov Loewinger, Geoff Hitchcox, Robert H. van Gent, Ali Cengia, Bob Cripps of The Eastbourne Astronomical Society (UK), Paul Gabriel, Martin Lewicki, Tariq Muneer, John Taylor, Robert H. Douglass, Jean Meeus, Mohammad Ilyas and Ernst Böck. I should also like to thank my wife, Sayra, for her support and help with digitising the world map.

Finally, a special "hello" to my daughters Zahra and Hanifa aged 4.5 and 2 years respectively when MoonCalc 6.0 was released. They were mainly responsible for the delay in the release of the new version :-)

## 6. Disclaimer

# 7. Glossary

- **Astronomical New Moon**

The moment when the sun, moon and earth are in one plane (in conjunction).

- **Altitude**

The angle up from the horizon. Positive above the horizon, negative below.

- **Azimuth**

The angle around from the north pole measured on the horizon in the sense NESW

- **Bright Limb Angle**

Difficult to explain without a diagram! Imagine a line joining the tips of the two limbs of the bright side of the moon. The BLA is 90 degrees + the anticlockwise angle between the celestial north-south axis and the above - mentioned line.

- **Conjunction**

See astronomical new moon.

- **Declination**

In the equatorial co-ordinate system, the angle measured perpendicular to the equator.

- **Elongation**

The sun-moon elongation is the angular separation of the moon from the sun as observed from a point on earth.

- **Latitude**

The co-ordinate expressing the angle (north positive, south negative) perpendicular to a fundamental plane. On the Earth the geographical longitude is the co-ordinate expressing the angle relative to the equator.

- **Libration**

Optical Libration: apparent oscillations of the moon due to the variations in the geometric position of the Earth relative to the lunar surface during the course of the orbital motion of the moon.
Physical libration: actual rotational motion of the moon about its mean rotation. Physical libration is much smaller than optical libration and can never be larger than 0.04 degrees in both latitude and longitude.

- **Longitude**

The co-ordinate expressing the angle round from a fixed direction measured in a fundamental plane. On the Earth, the geographical longitude is measured with respect to the equator.

- **Magnetic Declination**

The direction of magnetic north relative to true north. If positive, then magnetic north is east of true north. Magnetic Declination varies with time and location.

- **Parallactic angle**

The angle clockwise between the observer's zenith axis and the celestial north-south axis. The parallactic angle will vary with location and time of day. Knowledge of both the parallactic angle and the bright limb angle are needed to determine the orientation of the moon's limbs as observed in the sky.

- **Phase**

The area of the disc (of the moon or a planet) which is illuminated.

- **Positional angle of axis**

Counterclockwise angle between celestial axis and moon's rotational axis.

- **Right Ascension**

in the equatorial co-ordinate system the angle measured around from the point of Aries in the plane of the equator, in the sense SENW.

- **Terrestrial Dynamical Time (TD)**

An uniform time scale for accurate calculations defined by atomic clocks (unlike Greenwich Mean Time and Universal Time which are based on the Earth's rotation). The difference between TD and UT varies with time; currently TD-UT is about 1 minute.

- **Time Zone**

Longitudinal strip on the surface of the earth (approximately 15 degrees of longitude in width) where the zone time is a certain number of hours before or after GMT. This time is adopted as the local civil time by national or international agreement.

## 8. Abbreviations Used

| | |
|---|---|
| Alt | Altitude |
| Azi | Azimuth |
| BLA | Bright Limb Angle |
| Dec | Declination |
| DST | Daylight Saving Time |
| Elong | Elongation |
| Geo | Geocentric |
| GMT | Greenwich Mean Time |
| hr(s) | Hour(s) |
| LT | Local Civil Time |
| Mag Dec | Magnetic Declination |
| min(s) | Minute(s) |
| NYI | Not Yet Implemented |
| RA | Right Ascension |
| Rel Alt | Relative Altitude |
| Rel Azi | Relative Azimuth |
| Semi Diam | Semi-diameter of moon in degrees |
| sec(s) | Second(s) |
| TD | Terrestrial Dynamical Time |
| Topo | Topocentric |
| TZ | Time Zone |
| Width | Crescent width in minutes |
| UT | Universal Time |
| * | 1 hour added for DST/Summer Time |

## 9. General Moon Information

- Distance from Earth:

| | |
|---|---|
| centre to centre: mean: | 384,400km |
| closest (perigee): | 356,410km |
| furthest (apogee): | 406,697km |
| surface to surface: mean: | 376,284km |
| closest (perigee): | 348,294km |
| furthest (apogee): | 398,581km |

- Revolution period: 27.321661 days
- Axial rotation period: 27.321661 days
- Synodic period: 29d 12h 44m 2.9s
- Mean orbital velocity: 3680km/h
- Axial inclination of equator, referred to ecliptic: 1d 32m
- Orbital inclination: 5d 09m
- Orbital eccentricity: 0.0549
- Diameter: 3475.6km
- Apparent diameter seen from Earth:

| | |
|---|---|
| max | 33m 31s |
| min | 29m 22s |
| mean | 31m 5s |

- Reciprocal mass, Earth = 1: 81.3
- Mass = 7.35x10^25g
- Mass, Earth = 1: 0.0123
- Volume, Earth =1: 0.0203
- Escape Velocity = 2.38 km/s
- Surface Gravity, Earth = 1:0.1653
- Albedo: 0.07
- Mean magnitude at full moon: -12.7

## 10. Frequently Asked Questions

*Q. How do I capture and save a MoonCalc map or other MoonCalc graphics screen?*
A. The easiest way is to run MoonCalc under Windows. When MoonCalc has produced a graphics screen, press the "Print Screen" key (usually next to "Scroll Lock"). This captures the image to the clipboard. Next run a graphics program such as Paint Shop Pro. "Paste in" the captured image. Then reduce the image to 16 colours and save as a gif file or bmp file. The above capture trick works for resolutions upto 640x480 (i.e. not for 600x800 and 1024x768 modes).

*Q. How do I print out MoonCalc data?*
A. To printout the tables of data: on some systems running in pure DOS mode, pressing the "Print Screen" button should result in a printout. If the program is running in a DOS box from Windows, pressing "Print Screen" will make a copy of the table to the clipboard. Open Windows Notepad and "Paste in" the clipboard using Control & V. Make sure you are using a mono-spaced font such as Courier. You can now printout the Notepad screen. To printout MoonCalc graphics screen: on a pure DOS system pressing 'P' after a graphics screen has been printed out gives the option of printing out to a Epson or HP Laserjet printer. In Windows mode, you can capture the graphics as described in the previous question and printout using a program such as Paint Shop Pro (works for up to 640x480 resolution).

*Q. Why are the sunset, sunrise, moonset and moonrise times out by an hour?*
A. Either the time zone is entered incorrectly or daylight saving time rules have to be changed. The Time Zone that MoonCalc suggests are only approximate.

*Q. Why doesn't MoonCalc run properly under Windows 95/8?*
A. Make sure that the "start in:" or "Working directory" property of the desktop shortcut to the mooncc60.exe file points to the directory containing the MoonCalc files.

*Q. Why does MoonCalc crash with "runtime error 200" on my fast PC?*
A. This should not occur with MoonCalc 5 and higher although it used to occur with older version of the program. Basically, the error was due to a bug in the compiler used to write MoonCalc which caused an overflow when the program was ran on a fast Pentium computer. I have tested version 6.0 on a variety of fast PCs without problems.

*Q. Why does MoonCalc crash with "runtime error 207" on my PC?*
A. This is a erratic problem which seems to be related to the magnetic declination routine. I have not got to the bottom of it. Often running the program again sorts things out. If the error keeps occurring, try moving the magmodel.dat file out of the working directory - this bypasses the magnetic declination routines.

## 11. Conclusions

MoonCalc was developed over a period of 8 years and continues to be in a state of constant development. The program has given me a lot of pleasure to write and I hope very much that you enjoy using MoonCalc and find it useful.

Users of MoonCalc are encouraged to test the various functions of the program and compare the data produced by the program with actual sightings of the moon, particularly sightings of the crescent moon. All suggestions and comments which may improve the program are welcomed.

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http://www.ummah.org.uk/ildl/mooncalc.html

10th October 2001

## 12. Selected References

- **Computing and Astronomy**


1. Peter Duffett-Smith, 1992; Practical Astronomy with your Calculator;3rd edition; Cambridge University Press.

2. Peter Duffett-Smith, 1992; Practical Astronomy with your Personal Computer;2nd edition; Cambridge University Press.

3. Jean Meeus, 1988; Astronomical Formulae for Calculators; 4th edition; Willmann-Bell Inc; Virginia, USA.

4. Jean Meeus, 1991; Astronomical Algorithms; Willmann-Bell Inc; Virginia, USA. [2nd edition came out in 1999]

5. Montenbruck, O. and Pfleger,T; 1998; Astronomy on the Personal Computer; 3rd edition; Springer-Verlag, Berlin [4th edition now available]


- **Crescent visibility and lunar calendar**


6. Fotheringham J.K. On the smallest visible phase of the moon; Mon. Not.R. Astron. Soc. (1910),70:527-531.

7. Maunder W. On the smallest visible phase of the moon; J. British Astron Assoc (1911),21:355-62.

8. Indian Astronomical Ephemeris, 1979, India Meteorology Department, New Delhi.

9. Schoch, C. (1930) Tafel fur Neulicht; Ergaenzungsheft zu den Astronomischen Nachrichten (1930), 8(2): B17

10. Bruin F. The first visibility of the lunar crescent. Vistas Astron (1977):21:331-358

11. Mohammad Ilyas; A Modern Guide to Astronomical Calculations of Islamic Calendar, Times & Qibla,1984;Berita Publishing Sdn Bhd.; Kuala Lumpur, Malaysia

12. Mohammad Ilyas; Astronomy of Islamic Calendar, 1997; A.S Noordeen Publishers; Kuala Lumpur, Malaysia.

13. Mohammad Ilyas; New Moon's Visibility and International Islamic Calendar (for the Asia-Pacific Region 1407H-1421H), 1994; Published by Organisation of Islamic Conference (OIC) Standing Committee on Scientific and Technological Co-operation (COMSTECH) and Regional Islamic Da'wah Council of South East Asia and Pacific (RISEAP), Malaysia.

14. Schaefer B.E., Ahmad I.A. and Doggett L.; Records for Moon Sightings; Q.J. Ast. Soc. (1993), 34:53-56

15. RGO Astronomical Information Sheet No. 67; Prepared by HM Nautical Almanac Office, Royal Greenwich Observatory, Cambridge, UK. Also sheets 6,50,52,55,56,62,71,72,73,75&76. Most of these sheets were written by Dr. B.D. Yallop.

16. Schaefer B.E., Visibility of lunar crescent; Q.J R. Ast. Soc. (1988), 29:511-523

17. Ilyas M. Limiting altitude separation in the Moon's first visibility criterion. Astron Astrophys (1988),206:133-135.

18. Ilyas M. Lunar Crescent Visibility and Islamic Calendar; Q.J.R. Ast. Soc. (1994), 35:425-461.

19. Schaefer B.E., Length of the Lunar Crescent;Q.J.R. Astron. Soc.(1991), 32:265-277

20. Caldwell J. and Laney D. Young Crescent Visibility Predictions for 1997 (Islamic 1417/1418); South African Astronomical Observatory.

21. Doggett L.E. and Schaefer B.E., Lunar Crescent Visibility; Icarus (1994),107:388-403.

22. Schaefer B.E., Lunar Crescent Visibility; Q.J.R. Astron. Soc.(1996), 37:759-768.

23. Pepin M.B., In Quest of the Youngest Moon; Sky & Telescope, Dec 1996:104-106.

24. Yallop B.D., A Method for Predicting the First Sighting of New Moon; NAO Technical Note No 69; HM Nautical Almanac Office, Royal Greenwich Observatory, Cambridge, UK; first released June 1997, revised 1998.

25. Fatoohi L.J., Stephenson F.R. and Al-Dargazelli S.S., The Danjon Limit of First Visibility of the Lunar Crescent; The Observatory (April 1998), 118(1143):65-72

26. Eckhardt D.H. Theory of the libration of the moon. Moon and Planets, (1981) vol 25:3

- **Geomagnetism**

27. Chapman, S., and J. Bartels, Geomagnetism, Oxford Univ. Press (Clarendon), London and New York, Volumes 1 and 2, 1940.

28. Langel, R.A., The Main Field, in Geomagnetism, Volume 1, J. Jacobs (Editor), Academic Press, 1987.

29. Nelson H.J., L. Hurwitz and D. Knapp, Magnetism of the Earth, Publication 40-1 U.S. Department of Commerce, United States Government Printing Office, Washington, 1962.

30. Parkinson, W.D., Introduction to Geomagnetism, Scottish Academic Press, Edinburgh 1983.

- **Almanacs & Reference works**

31. The Star Almanac for Land Surveyors, HMSO, London.

32. Explanatory Supplement to the Astronomical Ephemeris, London.

33. Multiyear Interactive Computer Almanac (MICA) version 1.5; 1900-2005. US Naval Observatory; Willmann-Bell Inc; Virginia; USA.

34. Moore P.,Guinness Book of Astronomy, 4th ed, Guinness Publishing, Middlesex, UK

- **Internet**

35. Monzur Ahmed, Islamic calendar based on predicted lunar visibility.
International Lunar Date Lines;
Internet 1996-2001;  http://www.ummah.org.uk/ildl/
or http://www.starlight.demon.co.uk/ildl/

36. Monzur Ahmed, Regional Islamic Calendar;
Internet 1997-2001;  http://www.ummah.org.uk/ildl/zone3/
or http://www.starlight.demon.co.uk/zone3/

37. Monzur Ahmed, Astronomy and Islam
Internet 1997-2001;  http://www.ummah.org.uk/astronomy/
(Has extensive links to other related sites)