Development of Algorithms Under Matlab for the Study of Characteristics Motion Components Associated With Descending Moon Impact Probe (mip) and its Validation From Sequential Photo Images Aquired During the Descend From Chandrayan-1.

Prof. V.K. Srivastava   *ismkvinay@gmail.com*
Dept of Applied Geophysics
Indian School of Mines
Dhanbad, 826004, India

Mr. Tapas Kumar Nandy   *tapas.agp.ism@gmail.com*
Dept of Applied Geophysics
Indian School of Mines
Dhanbad, 826004, India

Mr. Anurag Verma   *anuragsverma@sac.isro.gov.in*
Space Applications Centre (SAC)
Indian Space Research Organization
Ahmedabad, 380015, India

Abstract

The present paper is an attempt to know the   motions characteristics associated with descending motion of Moon Impact Probe (MIP), a probe on board Chandrayan -1 designed to impact moon surface at pre decided location for scientific data collection from close range. For this, three independent motions viz.; spinning ,coning and translations were considered for a falling object and algorithms have been developed under MATLAB to simulate the surface trace from assumed parameters. Similar surface traces were generated using the time sequential images acquired by the descending MIP to moon surface without considering the three fundamentals motions as in first case. It has been observed that the two moon surface trace are quite similar which supports our assumptions of three above said independent motions. Such study is expected to provide a basis to choose suitable motion parameters for future MIP release to moon surface.

**Keywords :** Chandrayan1, Moon Impact Probe, Descending Motion, MATLAB

1. INTRODUCTION

Moon Impact Probe (MIP) is an unique, stand alone micro satellite probe which was released on 14th November 2008 from Chandrayaan-1, a first Moon mission of ISRO launched on Oct 22nd, 2008. The MIP was designed to impact at a pre-decided location on the moon with a purpose of scientific exploration of moon from the close range and to design, develop and demonstrate the technology required for deciding suitable impact site for probing the Moon. This MIP   took   about 25 min to impact near the south-pole surface of the Moon with a velocity of about 1.6 km/s. After separation, the MIP and the mother space craft Chandaryaan-1 were both in the same line of site so that the data send by the descending MIP could be received by the mother space craft as shown in fig no.1a and the details of instruments on board MIP is given below(Kumar et al 2009,Goswami et al 2009):

- Radar Altimeter – which measured the altitude of the probe during descent and provided information on qualifying technologies for future landing missions. The operating frequency band was 4.3 GHz ± 100 MHz.

- Video Imaging System – acquired close range images of moon's surfaces during descent at defined interval until its impact on moon's surface. The video imaging system consisted of an analog CCD (SONY ,Model XC 555 camera)camera.

- Mass Spectrometer – measured trace constituents of the lunar atmosphere during descent. This instrument was a quadrupole mass spectrometer with a mass resolution of 0.5 amu and sensitivities to partial pressures on the order of 1.3×10^{-11} pascal.
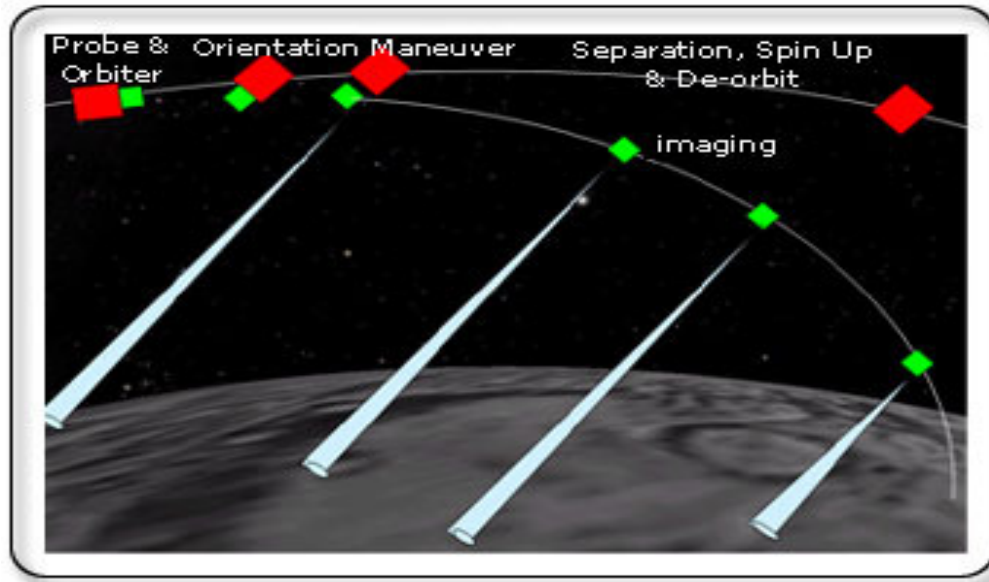

FIGURE 1a: The MIP mission profile

The present work specifically deals with the development of algorithm under MATLAB for simulating the pattern of surface traces assuming three basic independent fundamental motions of a falling body in space viz.; rotating ,coning and translational and comparing the same from the real surface trace patterns on moon derived from time sequential images acquired during the fall from the Chandrayan-1. Such basic understanding of motions could provide a basis for deriving motion parameters as well future landing sites for MIP.

2. METHODOLOGY AND DATA USED

Programs have been written in MATLAB from which surface traces were generated separately for 3-independent basic motions (see fig nos.2 to 4). There after algorithms were developed to generate surface traces due to composite motions of all three by taking some arbitrary values of these. In next stage moon surface traces of motion of descending MIP were mapped from about 3000 time- sequential corrected photo images of dimension 720*576 pixels, acquired after 25 minutes of journey at 20:31 Hrs IST covering the region in and around Shackleton Crater located in south pole region of moon (see fig no1b) and were received on 14th November 2008 by the Chandrayaan-1. This crater Shackleton has been the subject of intense study which is coincident with the south pole and is an unremarkable crater whose interior is almost completely in permanent shadows (Bussey et al 1999).The time interval between the two subsequent odd-even frames has been 20 m sec where as it is 1.72 m sec in between two subsequent even-odd frames ie time interval between each odd-odd pair is 1.72 sec. (these sets of data were provided by the Space Application Center of ISRO, Ahmedabad, India to junior author during his training program). Finally the surface traces of two motions , one from assumed motion data and the other from mapped real MIP motions have been generated and were then compared for verifying the nature of associated motions with descending MIP.
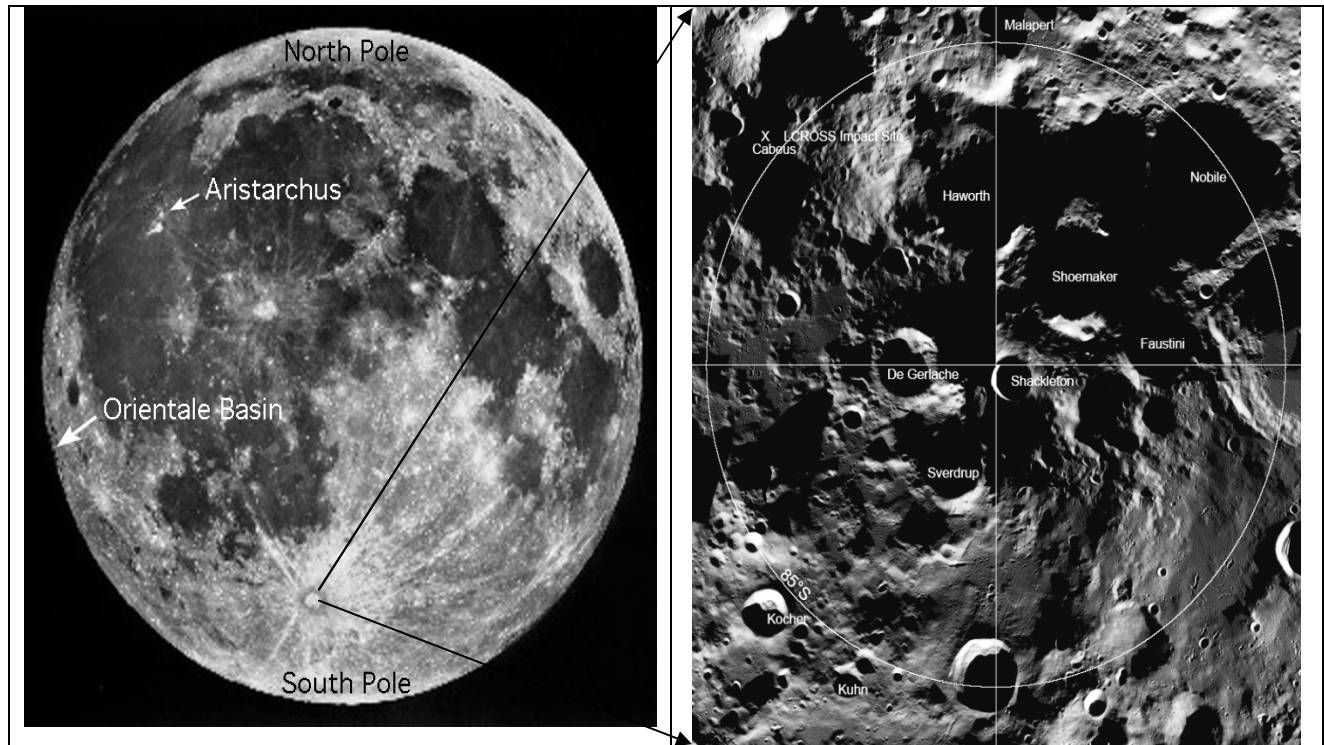
FIGURE 1b: LROC Wide Angle Mosaic of Lunar South Pole showing locations of major craters and Shackleton (modified after NASA/ GSFC/Arizona State University).

3. DEVELOPMENT OF ALGORITHM UNDER MATLAB ASSUMING THREE BASIC MOTIONS ASSOCIATED WITH ANY FALLING OBJECT UNDER GRAVITY VIZ.; SPINNING (ROTATION), CONING AND FORWARD TRANSLATION MOTION.

The following paragraphs discusses step by step the concept and algorithm for above mentioned three independent motions:

a. Spinning (rotation)
In rotation the each particle of the body moves in a circle and their center on a straight line, called axis of rotation and the perpendicular line to the axis of rotation from a point will sweep equal angle in equal time interval.

Let us consider a particle P rotating in 2D (x-y) plane with angular velocity w r p s (see fig 2a and 2b). The initial position of the particle is P(x0,y0), and after a certain time t the position is P'(x1,y1). The particle is rotating along a circular path having a radius

$$R = sqrt(x0^2 + y0^2) = sqrt(x1^2 + y1^2)$$

And the initial angle is $a = \tan-1\left(\frac{y0}{x0}\right)$.
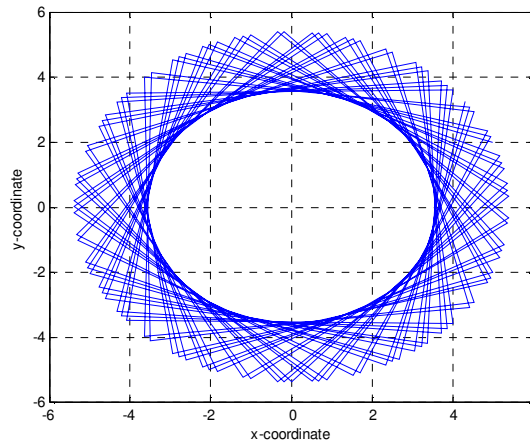
The particle sweep an angle b=w*t.
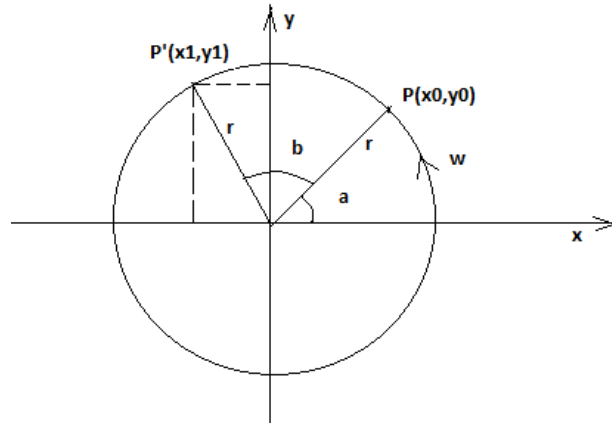
FIGURE 2a: Shows basic spining motion.
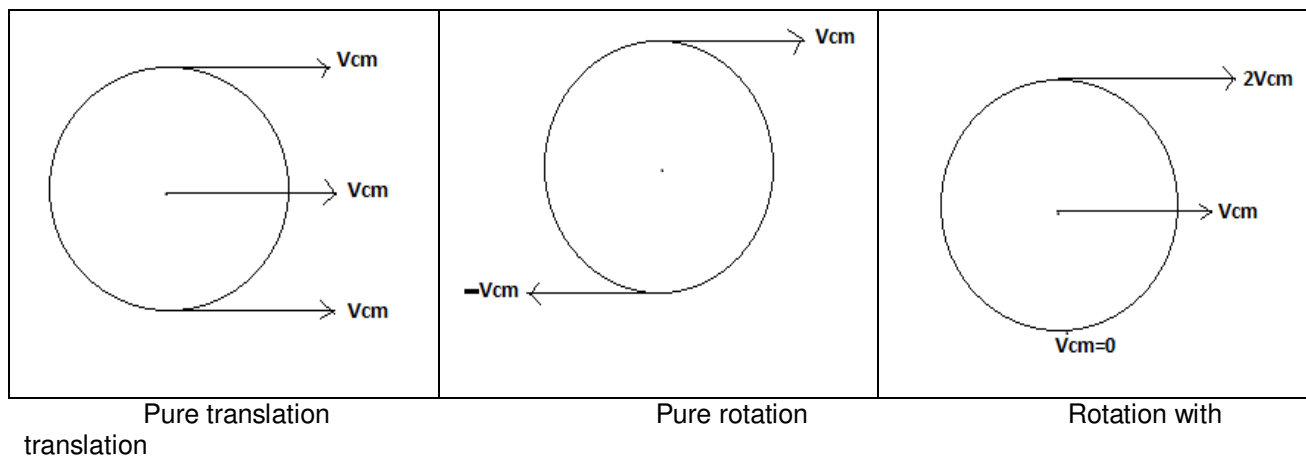
MATLAB program
```
t=0:.5:50;
x0=2;
y0=5;
w=72;
p=sin(w*t+atan(y0/x0));
q=cos(w*t+atan(y0/x0));
y1=sqrt(x0^2+y0^2)*q;
x1=sqrt(x0^2+y0^2)*p;
plot(x1,y1),grid;
```


FIGURE 2b: MATLAB plot for a body which is rotating about a fixed axis (spinning).

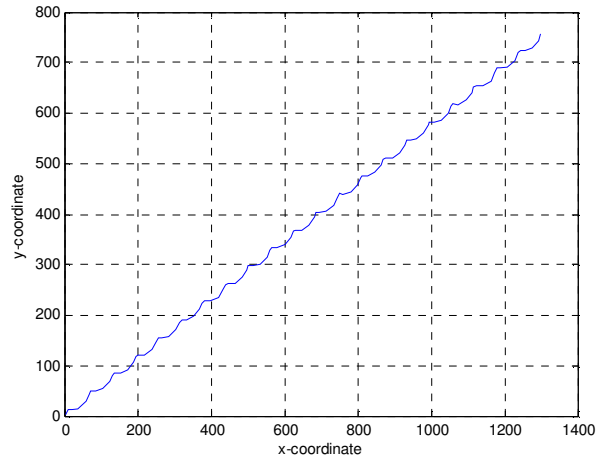**b. Spinning (rotation) Along With Translation Motion (see FIGURES 3a and 3b)**
If the rotating body is translating with the velocity V at an angle θ with respect to the horizontal then the composite motion shall be as shown below.

| Pure translation | Pure rotation | Rotation with |

translation

**FIGURE 3a:** Shows the basic spinning, rotational as well as combined rotational and translation motions.

MATLAB program

```
t=0:.5:50;
x0=4;
y0=5;
v=30;
w=500;
theta=pi/6;
p=sin(w*t+atan(y0/x0));
q=cos(w*t+atan(y0/x0));
y1=sqrt(x0^2+y0^2)*q+(v*sin(theta)*t);
x1=sqrt(x0^2+y0^2)*p+(v*cos(theta)*t);
plot(x1,y1),grid
```


FIGURE 3b: MATLAB plot describing the composite motion of rotation, and translation.
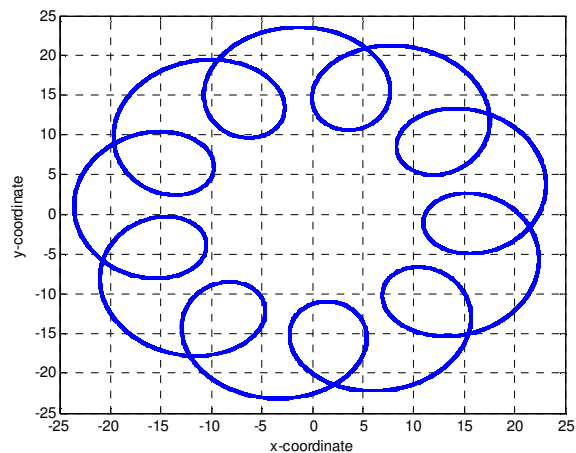
c. Rotation (spinning) Along With Coning
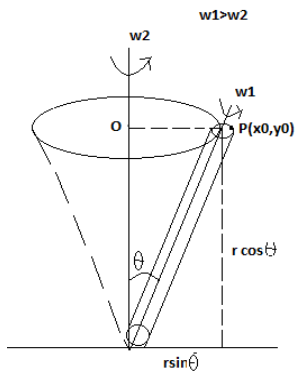
Here,
w1 is the spinning rate.
w2 is the coning rate.
r is the height of the camera.
θ is the inclination angle of the camera with the vertical

FIGURE 4a: This figure demonstrate the concept of coning motion along with spinning motion.

MATLAB program:

```
t=0:.005:2000;
x0=4;
y0=5;
h=30;
w1=100;
w2=10;
theta1=pi/6;
p=sin(w1*t+atan(y0/x0));
q=cos(w1*t+atan(y0/x0));
y1=sqrt(x0^2+y0^2)*q+(h*tan(theta1)*cos(w2*t)
);
x1=sqrt(x0^2+y0^2)*p+(h*tan(theta1)*sin(w2*t))
;
plot(x1,y1),grid;
```


FIGURE 4b: The MATLAB lab plot describing the composite motion of rotation along with coning.

Algorithm for Combined Spinning, Coning and Translation Motions of MIP (see FIGURE 5).

In this case we see the above in some modified way, i.e. we can see the effect of the above case along with the translation motion.

MATLAB Program

```
t=0:.25:80;
x0=4;
y0=5;
h=30;
v=10;
w1=600;
w2=300;
theta1=pi/4;
theta=pi/6;
p=sin(w1*t+atan(y0/x0));
q=cos(w1*t+atan(y0/x0));
y1=sqrt(x0^2+y0^2)*q+(h*tan(theta1)*cos(w2*t))+(v*sin(theta)*t);
x1=sqrt(x0^2+y0^2)*p+(h*tan(theta1)*sin(w2*t))+(v*cos(theta)*t);
plot(x1,y1),grid;
```
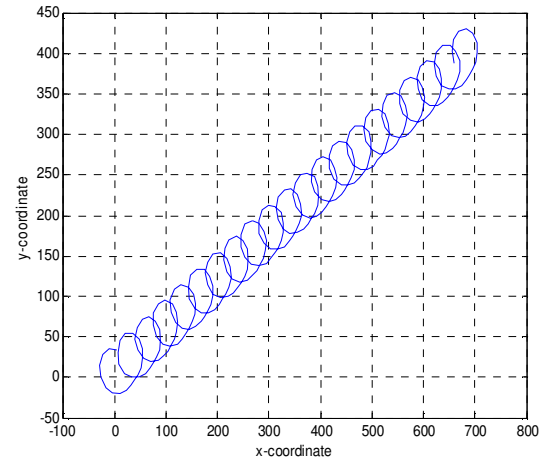

FIGURE 5: The MATLAB plot for the composite motions of rotation, coning and translation.

4. RESULTS AND DISCUSSIONS

Using assumed parameters and the algorithm developed under MATLAB the surface motion traces were generated without any consideration to real data. We have chosen some arbitrary values of the motion parameters and then computed the final position from the initial point. Thereafter we plotted the surface traces of the descending MIP having composite motions viz.; spinning, coning and forward translation motion.

Later similar ground motion traces were derived using the parameters derived from space sequential images acquired by the descending MIP of the Chandrayan -1 and on comparision with simulated one it is observed that both the traces are similar. This fact supports our basic consideration that the motion of descending MIP has three motion components as discussed and stated below.
The fig no.6 shows consecutive images of two frames of MIP which shows the features/objects are rotating and indicates the spinning motion of MIP about its axis.

In FIGURE 7, it is observed that the objects in the images are rotating and certainly they go away from the frame and after a certain time the objects are reappearing in the frames. So we can easily conclude that the MIP is spinning and also coning with respect to a certain axis.

In FIGURE 8, it is seen that besides rotation, the features in the images are moving in a certain direction which is opposite to the direction of the camera movement from which it is concluded that the camera is translating with a certain velocity.
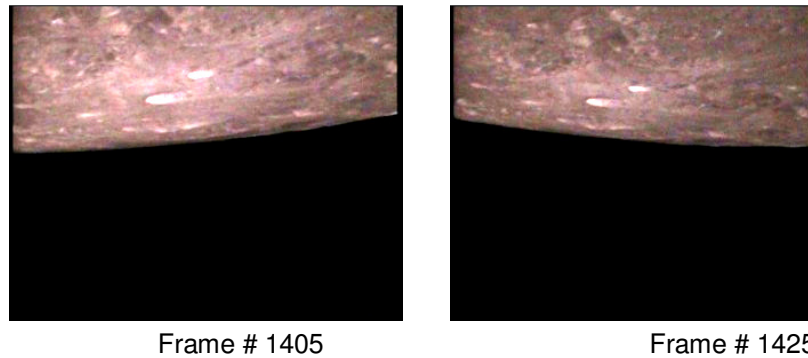
So it has been possible to verify three basic motions of descending MIP from traces as mapped from developed algorithms as well as from acquired images of MIP.
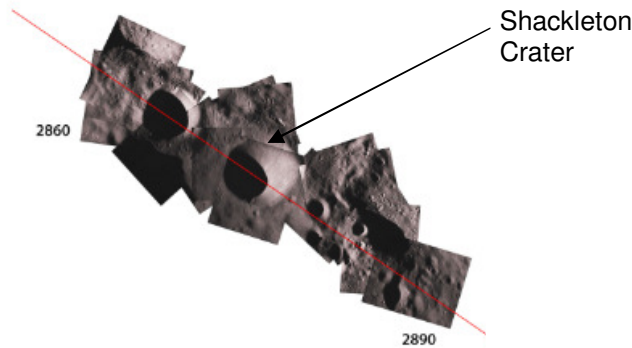
Frame # 2768   Frame # 2769

FIGURE 6: From these consecutive two frames (Frames # 2768 & 2769) we can get the idea of spinning of MIP

Frame # 1405   Frame # 1425

FIGURE 7: Almost after 20 frames the large crater reappears in these frames (Frames # 1405 & 1425) with small residual angle which support the motion due to coning.


Shackleton
Crater

2860

2890

Space sequential frames from #2860 to2890

FIGURE 8: From these space sequential frames (Frames # 2860 & 2890) we can observe that the MIP is moving in a certain direction and which support the forward translation motion.

5. CONCLUSIONS

From two final moon surface traces, one obtained from developed algorithm using arbitrary motion parameters of descending MIP (see FIGURE 9a) and other from real space sequential images acquired on 14th November 2008 by the descending MIP from Chandrayan-1(see FIGURE 9b) it is concluded that the descending motion of the MIP is composite of three independent fundamental motions viz.; Spinning, Conning and Forward translational. This is verifiable from the trace path along which the MIP has travelled during the descend to moon surface and if we see in the real de-rotated space sequential images we get the almost same traces followed by the MIP and is comparable to surface trace as simulated using developed algorithm by taking assumed motion parameters as well as considering the above mentioned three fundamental motion in space for a descending MIP on moon surface.
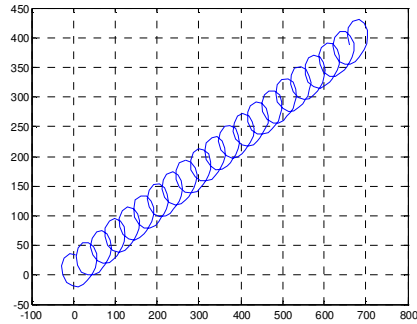
FIGURE 9a: Plot showing calculated moon surface trace of MIP motion derived from algorithms developed under MATLAB
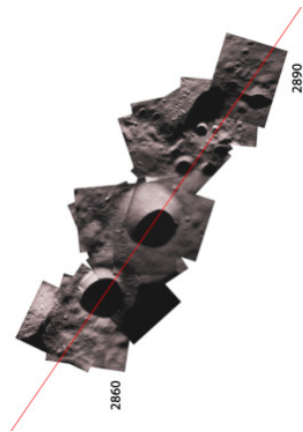
FIGURE 9b: The moon surface trace of path derived from the MIP space sequential Images.

From the developed algorithm it is possible to derive characteristics motion parameters of descending MIP from spacecraft in deciding the future impact site on moon surface. However it has not been possible to compare and verify the results further as very few number of publications are available on this aspect.

6. ACKNOWLEDGEMENT

7. REFERENCES
[1]   Bussey DBJ, BD Spudis and MS Robinson (1999) Illumination condition at the Lunar South pole, Geophysics Research Letter ,26,1187-1190.

[2]   Goswami J.N., M. Annadurai, (2009), "Chandrayaan-1: India's first planetary science mission to the moon" Current Science, vol. 96, no.4. page no.486-491

[3]   Kumar Ashok and MIP Project Team, 2009, "The Moon Impact Probe on Chandrayan -1" Current Science, Vol 96,No 4 Feb 2009 pp 540 – 543.