LIGO-India: Origins & site search

On behalf of the LIGO-India team

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IUCAA, India

Spokesperson (science),
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Member, Secretary
LIGO-India Scientific
Management Board

Project coordinator-IUCAA,
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LIMMA-2019
Dukes Retreat, Khandala
Jan. 15-18, 2019
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IndI GO Consortium – a brief history

• Dec. 2007: ICGC2007 @IUCAA: Rana Adhikari’s visit & discussions

• 2009:
  – Australia-India S&T collaboration (Iyer & Blair)
  
  Establishing Australia-India collaboration in GW Astronomy

• IndI GO Consortium: IUCAA Reunion meeting (Aug 9, 2009)

• 2009-2011:
  – Meeting with Intl committee at Kochi, Pune, Shanghai, Perth, Delhi
  – IndI GO accepted into the LIGO Science Collab. (LSC) : pan-Indian 7 institutes: 15 members

• March 2011: IndI GO-I Proposal: Participation in LIGO-Australia ~10-15%

• May 2011+: LIGO-India..
Rapid steps towards LIGO-India

- October 2011: LIGO-India included in the list of Mega Projects under consideration by the Planning commission

- Nov 2011: IndIGO submitted Project Proposal to DAE-DST Consortium proposing the consideration of LIGO-India as a Mega-Science Project in the XIIth five-year plan

- April 2012 – LIGO-India discussed at Atomic Energy Commission (AEC) meeting and approved

- August 2012 National Science Board go ahead for LIGO plans for relocating third detector to India
LIGO-India Site search

LIGO-India selection (Sept 2011 – Sept 2016)
39 site leads followed up
Recommendation for primary and backup site Sep 2016

Site selection report
Chaired by:
Ajit Kembhavi &
P. D. Gupta
LIGO-India site search requirements

Requirements:
- Low ‘seismicity’ (ground noise PSD)
- Low human generated noise
- Air connectivity, road connectivity, data connectivity,...
- Proximity to Academic institutions, labs, industry preferred, ...

Approach:
- Identify potential sites not too far from existing facilities
- Establish contact with local & high level state officials
- Desktop survey of sites, Followed by team visit
- 2-3wk seismic survey: ground noise PSD at 0.1-100 Hz range
- Site acquisition assessment
- Create a shortlist of best contenders

Details available in the Site selection document.
Site search evolution

Dec 2012
Dec 2011
1) Sept 2011: visit to Chitradurga site by Tarun, Albert Lazzarini, Stan Whitcomb

2) 28th March 2012: visit to Chitradurga site by Bala, Unnikrishnan and Tarun

3) 2nd to 16th April 2012: Seismic characterisation at site Chilmathur, Anantpur district, A.P.

4) 12th April 2012: Visit to site Udaipur-I(24o 41' N, 73o 56' E) (Vallabhnagar tehsil, Udaipur district), 7km from Udaipur, Rajasthan by Sharad Gaonkar, Unnikrishnan

5) 13th April 2012: Visit to site Udaipur-II, Vallabhnagar tehsil, Udaipur district, (24°42'30.00"N: 73°57'37.00"E), by Sharad Gaonkar, Unnikrishnan.

6) 13th April 2012: Bander Sindri(26° 34.1' N, 75° 01.5' E), near Kishengarh town, Ajmer district, of Rajasthan, by Sharad Gaonkar, Unnikrishnan

Details available in the Site selection document.
Early Site search

GENERAL VIEW OF SITE KALYANPURA
Kalyanpura, Dist. Udaipur, Rajasthan,
20th February 2014 (24 deg 41’ 30”, 74deg 9’ 54”)

SITE PIPLIYA KULMI, RAJGARH DISTRICT, M.P.

• 24 December 2012 Installation of Guralp seismometer at site Pipliya kulmi, Rajgarh district, M.P. (24 12’ 17.14”N, 76 20’ 44”)

COURTESY: SHARAD GAONKAR
Early Site search

Site search in vicinity of Lonar crater, Buldhana district, Maharashtra: May 2013

4 days Sharad, Sanjeev Dhurandhar, Kurtadikar at 45 degC+ (115F+)

19 53’ 40” 76 36’ 21”

( 19 56’ 6”, 76 28’ 32”)

Courtesy: Sharad Gaonkar
NOTE: We followed up ALL leads, independent of their seismic zonation. 20 site leads up until now (since Sept 2011)
Critical aspects of LI site selection

- **Technical requirements and restriction from scientific performance**
  (Basis for shortlisting of sites)
  
  i. Seismic noise power spectral density
  ii. Anthropogenic noise sources --- present & future
  iii. Operational logistics

- **Feasibility of Land Acquisition**
  Detailed site acquisition study for shortlisted site. Identifying plots to be acquired on village maps, ownership data, land acquisition procedure, time-lines & risks, with regard to LARR-2013

- **Engineering feasibility of LIGO-India base construction**
  Study by Tata Consulting Engineers Ltd. -- for site recommended
  Issues and concerns to be discussed for site (Apr 13, 2016 meeting)
  ① Annual rainfall and maximum intensity √
  ② High flood level √
  ③ Side slope of cut in proposed elevation √ [60 deg as per TCE report]
  ④ Feasibility of attaining proposed terrace level

Details available in the Site selection document.
Usage restrictions in Adjoining region

*Current + during >15 year Operations*

- NO sustained heavy equipment, mining, blasting activity in the vicinity (30km)
- NO Reciprocating power-plant machinery, rock crushers and heavy machinery (>16 km, prefer 40km from the site)
- Non-reciprocating power-plant machinery and balanced industrial machinery should be located at least 7km from the site, preferred distance of 16 km.
- Railway: >10 kms (preferably 16km) away from any busy railway track active at present, or, possible in the next 15 year.
- Roadways: More that 4-6 km from any major busy motor highway.
- Airways: More than 60km from any major airport. More that 20km from a not so busy (less than 5 flights/day) airport.
- No major water flows during most of the year near the site (The site should be 100 km to 200 km away from the sea-coast!)

*Details available in the Site selection events.*
Map showing the details of the land proposed for KSSIDC, ISRO, BARC, DRDO and IISc in R Sy No 47 of Kudapura, Varavu kaval, Ramadurga, Nelagettanahatty Villages in Nayakanahatti hobli, Challakere taluk, Chitradurga dist.

Option
• Acquire modest extra adjoining land

Iphone photo by Albert Lazzarini
Map showing the details of the land proposed for BARC, ISRO, KSSIDC in R Sy No 1 of Ullarthi kavalu Village, Talak hobli, Challakere taluk, Chitradurga dist.

- **Coloured area shows an extent of 473 acres - 20 guntas of land in R Sy No 1, proposed for ISRO.**

- **Coloured area shows an extent of 250 acres of land in R Sy No 1, proposed for KSSIDC.**

- **Coloured area shows an extent of 1410 acres of land in R Sy No 1, proposed for BARC.**

- **Coloured area shows an extent of 8 acres 36 guntas of land in R Sy No 1, presence of burial ground.**

- **Coloured area shows reserved area an extent of 1 acre - 20 guntas of land in R Sy No 1 proposed for Ashraya housing and raitha kana.**
Google Map of the Challakere area (14.436052N, 76.581438E).

Desktop study: Google maps, Bhuvan (ISRO)
Step 1: Google Earth map
With a proposed configuration
A desktop study: MP Site 2, Madhya Pradesh

Satellite Topography map with a proposed configuration

USGS ASTER GDM, resolution 1" by 1"
desktop study: terrain along arms

Courtesy: Rajesh Nayak
Space Application Centre ISRO
Remote Sensing data for LIGO-India site survey

- CARTOSAT satellites sensor was built by ISRO for mainly intended for cartographic applications

- The satellite images have a spatial resolution of 2.5 meter and cover a swath of 30 km.

- With stereo imaging capability it is enable the generation of Digital Elevation Models (DEM)
Engineering feasibility study

Completed July 2015

BIRD VIEW OF ARM-2
MIN. LVL. 356M, MAX. LVL. 378M
PROPOSED FOUNDATION: PAD FOUNDATION

LIGO INDIA AUNDHA SITE
PREPARED BY
TATA CONSULTING ENGINEERS LTD.

MAIN STATION
FOUNDATION AT EL 363M
As far as possible site shall be away from roads with high vehicular traffic and shall not cross the arms. If roads are inevitable then roads with low traffic and carrying light motor vehicles are acceptable. Roads crossing arms shall be provided with suitable overpass or underpass.

Time, efforts and cost required for construction of arms and infrastructure shall be optimized.

Land proposed for the project shall be barren and non-agricultural. As far possible land shall be under government control. Acquisition of agricultural land under private control is difficult to acquire and takes substantial time.

Every site shall be evaluated with respect to the above requirements. Section 2.0 evaluates Aundha site and provides rating to each parameter. Ratings are decided based on following criteria:

**EXCELLENT:** Meets all the requirement
**GOOD:** Meets the requirement with few minor exception
**MODERATE:** Slightly meet the requirement
**POOR:** Does not meet the requirement, major improvements needed to meet the requirements
Engineering feasibility study

ANNEXURE - 1 (SH.1)
ELEVATION PROFILE OF ARM-1 & 2
FOR AUNDHA SITE

ELEVATION PROFILE OF ARM-1

ELEVATION PROFILE OF ARM-2

Profile along Arm1 and Arm2
Geotechnical information

MRSAC Geological map of the area Site Aundha

Vesicular traps showing
- plateau moderately dessicated (33157 pink),
- plateau weathered shallow (3589 yellow),
- plateau slightly dissected (33157 brown),
- Plateau undissicated (33157 dark brown Dudhala)
Water catchment & drainage area

Support for the water divide existing between the Kayadhu basin to the east and the minor nalas flowing to the west of the Siddheshwar dam from the Dudhala-Anjanwara ridge is provided by following maps to be discussed.

Fig. 4: Google earth image superposed with proposed arm layout for LIGO-India and representative elevation section across W-E line drawn from Siddheshwar reservoir to Dughala ridge through the site Aundha. The proposed LIGO layout of two arms in perpendicular directions and each of four km length is shown in sky blue colour to east of Siddheshwar reservoir. Yellow line further to east shows the road from Aundha in south to Hingoli in north. Eight parallel traverses each of length 10 km were drawn from west to east from Siddheshwar dam in west towards Aundha-Hingoli road to east over the Google earth image and the elevation profiles were studied along these traverses. One of the representative elevation profiles is shown along line L3. The elevation section has brought out the location of the Dudhala-Anjanwada ridge by cutting across the elevated region. The two edges of the ridge were marked along this line as well as other eight traverses to north and south of this line. The ridge extremities on west and east are traced by the two purple lines. This exercise clearly shows that the Dudhala-Anjanwada ridge extending for more than 14 km separates the eastern water basin from the western water basin in which the site Aundha is located.
Weather & Climate

Average wind speed (Km/Hour) at three wind stations in Aundha tehsil, Hingoli district, Maharashtra

Percentile values for wind speed (Km/Hour) for wind data from AWS, Hingoli for period 2012 to 2014
CARTOSAT (ISRO) terrain data for a Aundha site. Overlays show a proposed LIGO-India configuration, the existing roads, villages, waterbodies and streams.
## Table: Survey Details

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Kalyanpura (Rajasthan)</th>
<th>Aundha-Nagnath (Maharashtra)</th>
<th>Rajgarh-I, MP (Kalitalai)</th>
<th>Rajgarh-II, MP (Pipliya Kulmi)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Seismic survey</strong></td>
<td>Good, unknown bump at 1-2 Hz</td>
<td>Good</td>
<td>Good, unknown bump at 1-2 Hz</td>
<td></td>
</tr>
<tr>
<td><strong>Land mass movement</strong></td>
<td>23 m cubic m (very flat)</td>
<td>66 m cubic m (small streams)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Land ownership</strong></td>
<td>Private, agriculture, small villages and roads</td>
<td>Government, no cultivation, grazing land. Small village, nearby reservoir</td>
<td>Rocky barren land. Land ownership and availability details to be followed up with the collectorate.</td>
<td></td>
</tr>
<tr>
<td><strong>Nearest City (population)</strong></td>
<td>Udaipur (0.6m)</td>
<td>Nanded (0.55m)</td>
<td>Bhopal (1.8m), Indore (3.3m)</td>
<td>Rajgarh (24k) distance: 10km, 56km</td>
</tr>
<tr>
<td><strong>Airport</strong></td>
<td>Udaipur (100km) Ahmedabad (183km)</td>
<td>Nanded (60km) [operation paused] Aurangabad (191km) Indore (476km) Hyderabad (358km) Pune (412km)</td>
<td>Bhopal (134km) Indore (215km)</td>
<td>Bhopal (186km) Indore (191km)</td>
</tr>
<tr>
<td><strong>Hotel</strong></td>
<td>Many hotels in Udaipur</td>
<td>Few good hotels in Nanded</td>
<td>Many hotels in Bhopal &amp; Indore</td>
<td></td>
</tr>
<tr>
<td><strong>Distance from nearest hotel</strong></td>
<td>100km</td>
<td>60km</td>
<td>200km</td>
<td></td>
</tr>
<tr>
<td><strong>University</strong></td>
<td>Udaipur has universities with MSc Physics dept. It also has an observatory. There are people involved in X-ray analysis. There is an IIM too.</td>
<td>Nanded SRTM University and many more. Has M.Sc. Course in Astronomy. Hosts a IRC and has build a small cluster. Has good people in seismology.</td>
<td>Many small universities and P.G. Colleges, e.g., Jaypee Univ. Of Engineering and Technology.</td>
<td>Indore has IIM and IIT.</td>
</tr>
</tbody>
</table>
Engineering feasibility study
Aundha, Hingoli, Maharashtra

Figure 18 Existing road network
Figure 19 Proposed modification to road network
Seismic study

Aundha site, Hingoli District, Maharashtra (near Nanded)
[Sep 29-Oct 15, 2013]
Seismic Survey (RJ-1, Nov. 8, 2012)

Himangshu, St/o Supriyo
Unni
Sharad Goankar, Sr. consultant IUCAA
Prof. Jaafrey, IUCAA Assoc. IRC Udaipur Univ

Jan 16, 2013
GW - New Frontiers, Seoul
Seismic study
Aundha site, Hingoli District, Maharashtra (near Nanded) [Sep 29-Oct 15, 2013]

Noise level at US detector site (cyan)

Noise level at our site (red)
Micro-Seismic study
2 year data at Nanded College seismological observatory

Histogram for 687 Number of days

\[ f_{\min} = 0.07 \text{ Hz and } f_{\max} = 0.4 \text{ Hz} \]

Median amplitude

- \([N]=4.587 \times 10^{-8} \text{ M}\)
- \([E]=4.083 \times 10^{-8} \text{ M}\)
- \([V]=5.1301 \times 10^{-8} \text{ M}\)

95% of events below amplitude

- \([N]=1.362 \times 10^{-7} \text{ M}\)
- \([E]=1.456 \times 10^{-7} \text{ M}\)
- \([V]=1.503 \times 10^{-7} \text{ M}\)
LIGO-India ‘preferred’ site

Pre-monsoon

Spring bloom

Post-monsoon
LIGO-India ‘preferred’ site

Dec 2013

Dec 2015
LIGO-India ‘preferred’ site

LI-PMB visit

Site acquisition
Team visit
Campus land near LIO site
Summary

• Continued top level support and goodwill for LIGO-India

LIGO-India site acquisition “COMPLETE”. Critical steps passed.

Work towards launch of Civil construction. Prototyping Vacuum infstruc

Developing scientific HRD through pan-Indian R&D program

Thank you !!!

• Enormous challenges ahead, but good progress so far !!!