

# The Third Generation Detector Pie and the Slices for Three Continents

Márka Szabolcs with the help of the **3G<sup>2</sup>WD** Team  
Columbia University in the City of New York

[LIGO-G1001099](#)

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ET 3<sup>rd</sup> Annual Workshop  
Budapest, MTA,  
Hungary

*"If I'd asked people what they wanted, they  
would have asked for a faster horse"*  
**Henry Ford**

I will summarize the result of a brief survey covering America, Australia, Japan, China and India regarding the status of future gravitational wave detector instrumentation plans. I will provide a succinct overview of the visions and research towards the enhanced advanced interferometers and the third generation detectors. I will also summarize what are the major established and upcoming new players are planning in this respect.



# Initiated Survey on Interest/Work in Third Generation Gravitational-wave Detector (3G<sup>2</sup>WD) Instrumentation Status, Plans, and Visions

- **Cast a wide net**
- *Already* received many responses
- Special thanks to

- Guido Mueller
- Dave Reitze
- Stan Whitcomb
- Norna Robertson
- Andrea Lommen
- David Shoemaker
- Scott Ransom
- Rana Adhikari
- Mike Zucker
- Dennis Ugolini
- Rainer Weiss
- Jan Harms
- Unnikrishnan. C. S.
- David Tanner
- ...and many others...

for the extensive input and information

***In a nutshell:* The interest and expertise for 3GGWD is significant**



... and many others are and will be interested ...

## Basic Conclusions...

- **Vision without funding is hallucination...**
  - aLIGO, AdV, and LCGT must work and discover to enable 3G<sup>2</sup>WD
    - Must concentrate on Second Generation and make it a success(!)
  - New GW detector generations need ~15 years of R&D effort
- **We have a team...**
  - A *single* team is needed and will form...
  - Interest is high
- **We need a firm foundation and realistic goals for the short term...**
  - First a scientifically motivated and sound **Reference Design...**
  - ... followed by a technically well defined and firm **Baseline Design...**
  - ... leading to the **Project!**
- **2025 is very ambitious** ... error bar is large...
- **Need to closely collaborate with Einstein Telescope...**



## Individual Interest and the Three Major Team Efforts...

- **Physics Frontier Center proposal**
  - Pre-Proposal to NSF is a SUCCESS!
  - -> Baseline design development and Basic research infrastructure
- **Advanced Interferometer Configurations White Paper**
  - <https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=9277>
  - <https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=11613>
  - -> Enhanced Advanced LIGO and Risk mitigation
- **LSC Instrument Science Working Groups**
  - <https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=13550>
  - -> Technological foundations and Project development
- **Many talented individual groups are pursuing their expertise towards 3G<sup>2</sup>WD**
  - -> Time to enjoy many flowers blooming!
- **Complementary, Comprehensive, and Collaborative!**



## Very Important: Present LSC Instrument Science Working Groups are already engaged in 3G<sup>2</sup>WD R&D and Planning...

- Global/System level considerations and coordination
  - Explore viable interferometer geometries
  - Underground and facility reuse options
  - Squeezing, alternative readout, all reflective interferometers?
  - Astrophysical motivators
- R&D, Engineering, and Noise considerations
  - Critical technical aspects need to be identified
    - Test mass size and suspension strength limitations?
    - Substrate and coating thermal noise limitations?
      - Cryogenics?
    - High vs. Low power operation?
    - Gravity Gradient (Newtonian) noise?
    - Alternative test mass materials?
    - How much gas damping can be mitigated?
- Essentially, a comprehensive range of R&D is proposed and planned
  - Redundancy with European and Japanese research?
  - **Coordination**, competition or divergence?
- Australia is an essential and mission critical player
  - Fully integrated collaborative research

Nice!



<https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=13550>  
<https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=116113>

# Physics Frontier Center proposal

- **Proposal spearheaded for the full *Community* by**
  - University of Florida
  - Syracuse University
  - University of Minnesota
  - Rochester Institute of Technology
  - Franklin & Marshall College
  - + many affiliated experts from the gravitational wave and astrophysics communities
  - Collaboration with ET and LCGT is essential
- **Fundamental deliverables proposed towards 3G<sup>2</sup>WD**
  - Major research infrastructure to be created at UF
    - Propose to serve the entire instrument community
  - Series of workshops proposed for community building
  - Proposed to develop a conceptual design for a third-generation interferometer
    - 'concept design informed by strong integrated astrophysics, data analysis, and numerical relativity component
  - Proposed to coordinate and perform research targeting these fundamental noise sources
    - GGN, Cryogenics, Silicon mirrors, Suspensions, Novel readout schemes, ...
  - Pre-Proposal to NSF is a SUCCESS!
- **Talented experts building the community**



Future Location of User Facility at UF



# Location of 3G<sup>2</sup>WD

- Needs global effort and global investment...

- What guidance aLIGO/AdV/LCGT discoveries will provide?

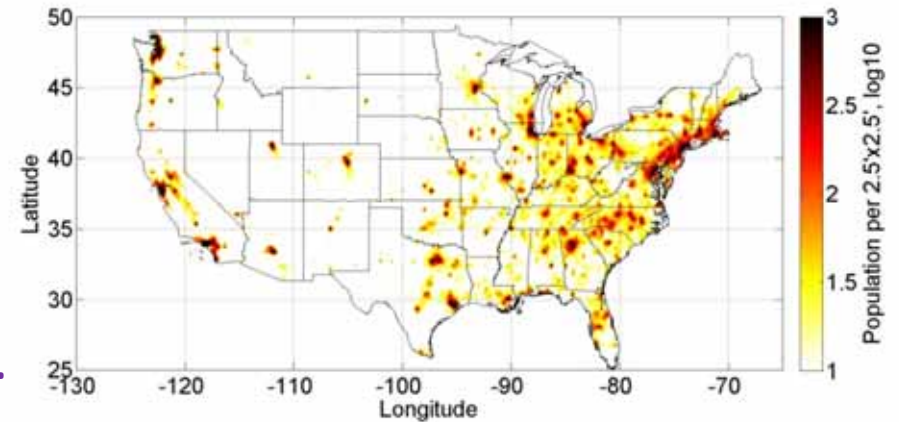
- Look for what is discovered already with higher SNR?
- Look for what is not discovered yet?
- Hard decisions are awaiting the community...

- Reusing aLIGO facilities for High-Frequency sensors ?

- Surface installation
- What is the role of the resonant bar technology?

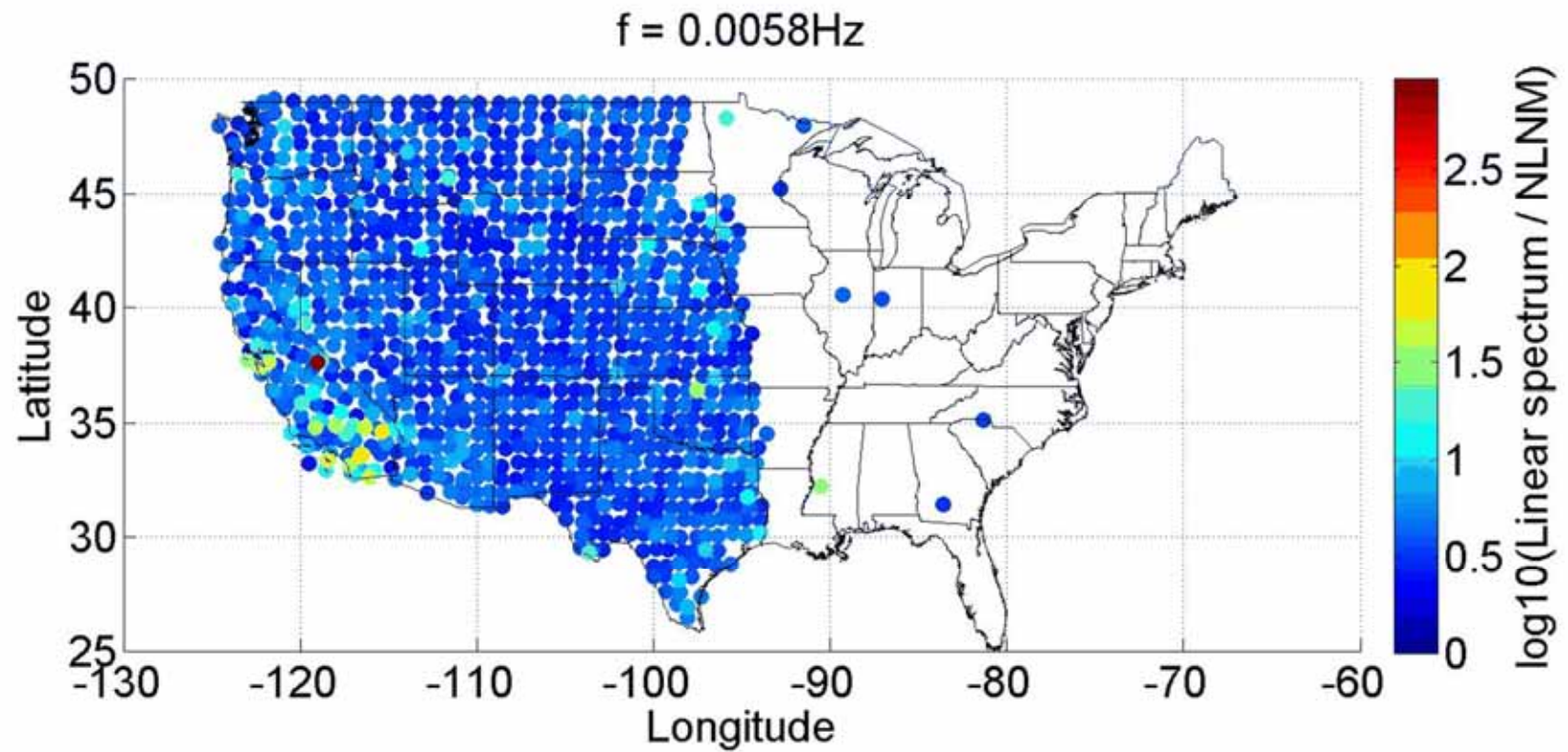
- Underground facilities for Low-Frequency sensors?

- 1-2 G\$ investment in a few years
- Many practical challenges
- Major R&D is needed to make it feasible
- Need to start now... What fraction of available resources should be devoted to R&D?

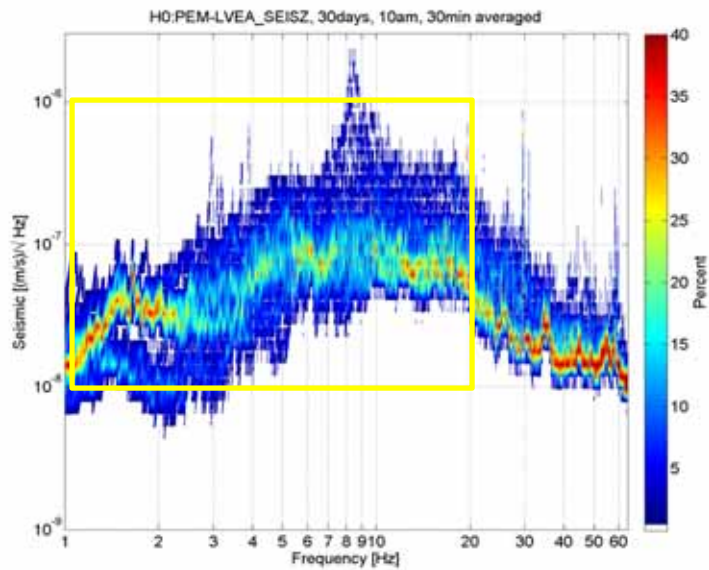
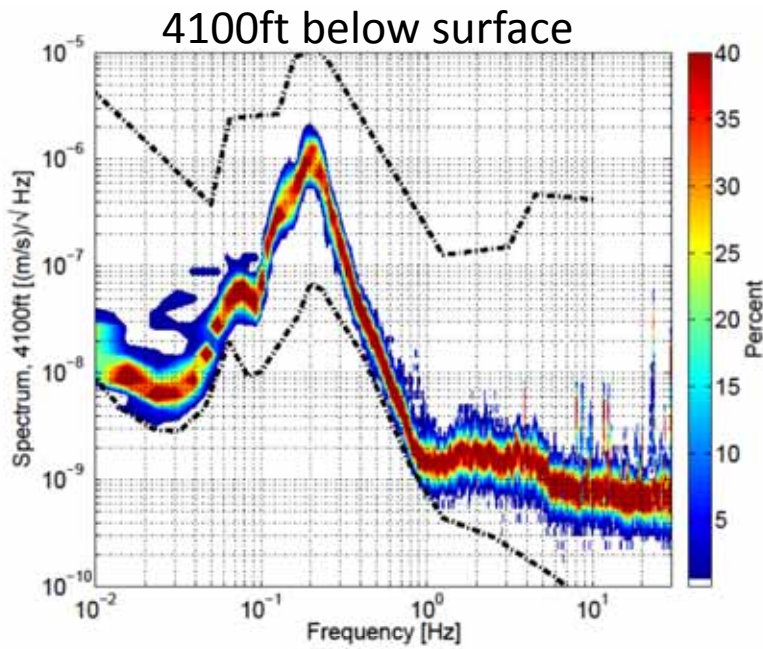




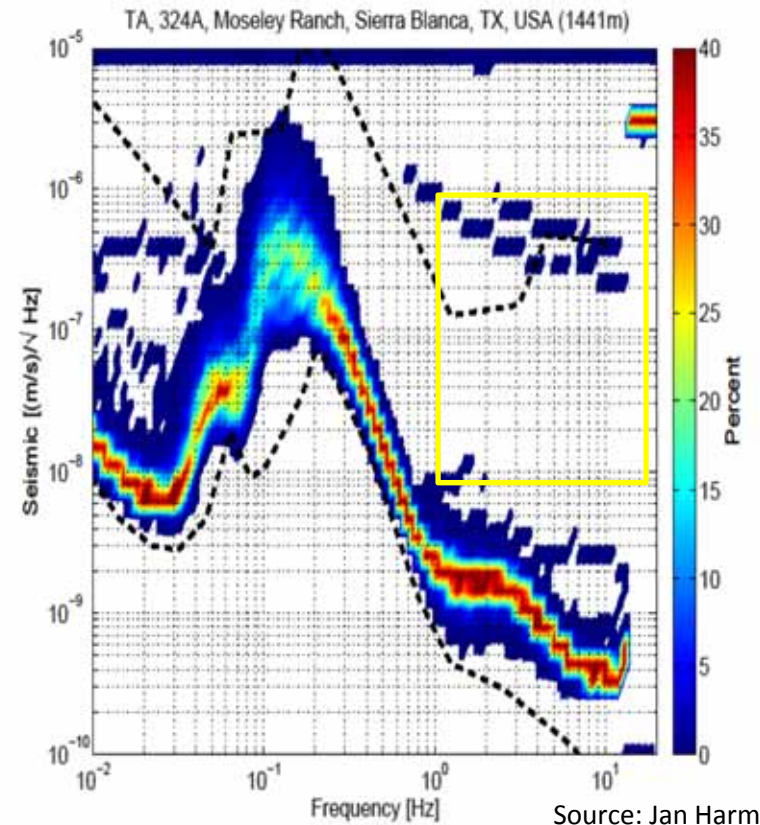
# Seismicity::US.Average



# Seismicity::Underground



LHO, LIGO



Source: Jan Harms

# LCGT – an exciting opportunity for large scale tests for 3G<sup>2</sup>WD tech



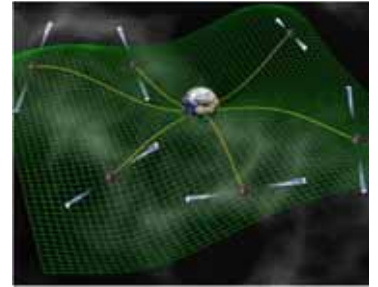
## IndIGO: India's 3G<sup>2</sup>WD Plans

<http://www.gw-indigo.org/tiki-index.php>

- Construction and operation of an advanced 3 meter scale prototype within the next three years
  - India needs to build experience
  - Funded prototype project
  - Planned sensitivity approaching  $10^{-18}$  m/sq.rt(Hz) above 200 Hz
    - Squeezed light technology in our prototype plan
    - Prototypes are considered merely for technology demo
- Collaborative participation in the 4 km class advanced detector.
  - Australia has shown interest in exploring close collaboration with India for participation in its AIGO detector.
- Feasibility study and construction of an advanced prototype in the 30 meter class in a carefully chosen place with full implementation of all the advanced detector technologies with similar or suitably scaled specifications for vibration isolation, mirror suspension, control system, lasers and vacuum etc., of the full scale km class detector, to be implemented within 5-6 years
- Construction of a 4 km class detector, Indian Interferometric Gravitational wave Observatory (IndIGO), as the final step. With the accumulated experience from the earlier steps, one may expect that such a detector to come up during 2020-22.
- ...



# Pulsar Timing 3G<sup>2</sup>WD



- **Gen 1:** Long term timing of a couple individual pulsars
  - show that they potentially have the stability necessary to probe interesting strain levels
- **Gen 2:** The use of ensembles of pulsars to attempt to detect GWs
  - correlated signal in the timing residuals of the pulsars
  - Parkes Pulsar Timing Array (PPTA)
  - European Pulsar Timing Array (EPTA)
  - NANOGrav,
  - -> combined efforts of the above as the *International Pulsar Timing Array* (IPTA, hopefully soon).
- **Gen 3:** Need preferably the equivalent of several hundred-meter-diameters worth of collecting area
  - Southern hemisphere
  - Next generation large-scale telescope(s) will probably be general-purpose astronomical instruments
  - MeerKAT telescope (Square Kilometer Array (SKA) "pre-cursor")
    - ~100m-diameter collecting area
    - roughly \$200M.
    - MeerKAT or FAST (in China) will come online in ~2015 or 2016 and they will definitely contribute strongly to pulsar-based GW detection efforts.
  - Several billion dollars for the SKA (equivalent of ~20-30 100m-class telescopes)
  - Convince the astronomical community that a very expensive international and multi-purpose facility like the SKA is crucial to the future of astronomy in general?
    - Need to wait until Astro2020 decadal survey?
  - Convince the physics community that building a specialized telescope specifically for pulsar-based GW detection is as worthy a goal?

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