GWIC
Gravitational Wave International Committee

The GWIC Roadmap

GWADW, Fort Lauderdale,
May 2009

Sheila Rowan for the Gravitational Waves International Committee (GWIC) Roadmap Subgroup

G0900622-v1

What is GWIC (Gravitational Wave International Committee)?

- Body formed in 1997 to facilitate international collaboration and cooperation in the construction, operation and use of the major gravitational wave detection facilities world-wide
- Affiliated with the International Union of Pure and Applied Physics as a sub-committee of IUPAP's Particle and Nuclear Astrophysics and Gravitation International Committee (PaNAGIC)
- Formally, similar status to ICFA (International Committee for Future Accelerators)

GWIC
Gravitational Wave International Committee

Who is GWIC?

ACIGA Jesper Munch

ALLEGRO William O. Hamilton

AURIGA Massimo Cerdonio

EXPLORER/NAUTILUS Eugenio Coccia

Einstein Telescope Michele Punturo

European Pulsar Timing Array Michael Kramer

GEO 600 Karsten Danzmann, James Hough (Chair)

LIGO, including the LSC Jay Marx, Dave Reitze

LISA Thomas Prince, Bernard Schutz, Robin Stebbins, Stefano Vitale,

Theory Community Clifford Will

MiniGRAIL and other Spherical Acoustic Detectors Giorgio Frossati

NANOGrav Andrea Lommen

Parkes Pulsar Timing Array Dick Manchester

TAMA/CLIO/LCGT Seiji Kawamura, Kazuaki Kuroda

VIRGO Francesco Fidecaro, Benoit Mours,

Executive secretary Stan Whitcomb

GWIC goals

Promote international cooperation in all phases of construction and exploitation of gravitational-wave detectors;

- Coordinate and support long-range planning for new instrument proposals, or proposals for instrument upgrades;

- Promote the development of gravitational-wave detection as an astronomical tool, exploiting especially the potential for coincident detection of gravitational-waves and events in other fields (photons, cosmic-rays, neutrinos);

- Organize regular, world-inclusive meetings and workshops for the study of problems related to the development and exploitation of new or enhanced gravitational-wave detectors, and foster research and development of new technology;

- Represent the gravitational-wave detection community internationally, acting as its advocate;

- Provide a forum for the laboratory directors to regularly meet, discuss, and plan jointly the operations and direction of their laboratories and experimental gravitational-wave physics generally.

GWIC roadmap origin

- At GWIC meeting held in Sydney, July 2007, GWIC members voted to initiate the Roadmap and charge a Roadmap committee to carry out the task
  - Develop a strategic plan that lays out the excitement of the field, the potential great discoveries and the facilities and resources needed to reach that potential
    - Ground-based, space-based, including pulsar timing, CMB polarization
- Goals of Roadmap-
  - Plan that global GW community can rally round and advocate
  - Excite other scientists & funders about great opportunities in field, its potential impact and synergy with other sciences
  - Show we have a realistic and coherent science-driven plan

Roadmap Committee Membership

- **Representing**
  – Space and ground-based community
  – Major projects, world-wide
  – Asia, Europe, US, Australia
  – Astrophysics, instrument science
  – Theory, experiment

- **Committee members**
  – Benoit Mours,
  – Cliff Will,
  – David McClelland,
  – Flavio Vetrano,
  – Jay Marx (chair),
  – Jim Hough (ex-offico)
  – Karsten Danzmann,
  – Kazuaki Kuroda,
  – Stan Whitcomb,
  – Sheila Rowan,
  – Stefano Vitale,
  – Sterl Phinney,
  – B. Sathyaprakash (co-opted)

Why do we want a GWIC Roadmap?

- Need to be able to speak with a strong voice as the current generation of detectors mature and new detectors begin planning
  - Higher cost projects may require greater international collaboration
  - Need to communicate the importance to funding agencies

- Increasing competition between GW projects and projects in other fields
  - E,g, “Beyond Einstein” prioritization by NASA
  - Need to make a strong science case to our colleagues in other fields

- Ensure that key future R&D directions are properly explored

Charge to GWIC Global Roadmap committee

- Develop global roadmap for field with 30-year horizon.
- Identify relevant science opportunities and the facilities needed to address them.
- Consider ground and space based capabilities, theory and numerical relativity, and possible impact of new technologies and approaches
- Take account known national and regional planned projects.

A perspective to optimize the global science in the field should form the basis for this roadmap. Roadmap should address what should happen and when, to reach goals in a timely manner--key decision points, strategies, etc.

Roadmap topics

- The long-term scientific value of the field and how it fits into the larger scientific landscape

- Anticipated **scientific opportunities** utilizing gravitational waves in the 10, 20, 30 year horizon and the facilities and capabilities needed to reach these opportunities

  – The scientific value of existing and planned **facilities** in the perspective of a global network

  – **Theory and numerical relativity** —anticipated developments and impact on the science capabilities of the field

  – Impact of **technologies**

    Projected new technologies that will improve capabilities.

    Impact of technologies developed in our field on other fields of science

Constraints etc

- Pre-existing community/government expectations for existing/proposed projects
  - Expectations our community has raised for future projects (don't undercut visions already articulated)
  - Keeping the fine line between optimism and realism – maintaining the credibility of the Roadmap

- Other Roadmaps that speak about GW--
  - e.g. ASPERA which has GW part of astrophysics
  - ASTRONET Roadmap

- Avoid problem of conflicting strategies, plans, etc

Big picture of Roadmap process

Via meetings of Roadmap committee:

- Report outline drafted
- Active subgroups focusing on science opportunities, ground & spaced-based developments, impacts of other fields.
- Gathering input & advice from within field, from neighbouring sciences, from funding agencies…..

Meetings, meetings, meetings

- Monthly teleconference involving people from Asia, Australia, US, Europe began September 2007

- Face-to face meetings (several days)
  - At Pasadena, US in March 2008
  - At Elba, Italy in May 2008

Working subgroups

Set up as the mechanism to get much of the work done

- Each has a well defined topic and charge—
  - e.g. subgroup 5 charge---*lay out a science-driven strategy for the space-based experimental and the theoretical and numerical capabilities and developments needed to address the anticipated scientific opportunities for the next few decades.*

- Subgroup Members -- ~3 from Roadmap committee
- Subgroups interacted with other people in field for information gathering and help
- Evolving subgroup reports were discussed with full committee at meetings, distributed to full committee for comments
- Each subgroup report formed the basis of a key chapter in the roadmap report

Roadmap Outline

0. **Executive summary** including major conclusions and recommendations
1. **Introduction**---what is GWIC, why a roadmap, this committee, members, process
2. **Introduction to Gravitational Wave Science**
3. **Current state of the field**
4. **Scientific opportunities in gravitational wave science now and in the next several decades**
5. **The future of the field in response to anticipated scientific opportunities—on the ground**
6. **The future of the field in response to anticipated scientific opportunities—in space**
7. **Impact of gravitational wave science on other fields**
8. **Recommendations to GWIC to guide the development of the field**
9. **Conclusions**

Getting input/advice/information from outside the committee

Avoided talking only to ourselves

- Got views from key audiences for roadmap – our field, related fields of science, funding agencies

- Roadmap committee has spent a lots of time listening to--
  - Input and advice from “wise people” both inside and outside our field
  - Perspective of funding agencies that fund GW science

- Solicited input from our community

Charge to “wise people”- tell us….

- *Your views about where the GW field will and should go in the next several decades and why*.
- *Your views about how the field will fit into the broader scientific perspective, interact and influence other fields, and be influenced by other fields.*
- *How should we interact with other fields (neighbouring) and funding agencies to communicate our vision and gain understanding if not support?*
- *How do you see the future accomplishments in gravitational wave science impacting your and other fields of science and technology?*
- *Can you imagine any synergy with other fields that we should work to enhance?*
- *Anything else?*

Scientists consulted:

Barry C. Barish
Linde Professor of Physics, Emeritus at the California Institute of Technology

Peter Bender
JILA Fellow

Eugenio Coccia
Director of Gran Sasso National Laboratory

Adalberto Giazotto
INFN Director of Research, INFN Pisa

Craig Hogan
Director of the Center for Particle Astrophysics at the Department of Energy's Fermi National Accelerator Laboratory and Professor of Astronomy & Astrophysics at the University of Chicago.

Anneila Sargent
Benjamin M Rosen Professor of Astronomy at the California Institute of Technology

Bernard Schutz
Director, Max Planck Institute for Gravitational Physics, Potsdam

Rainer Weiss,
Professor of Physics, Emeritus, Massachusetts Institute of Technology

Representatives of funding agencies-- have met with us:

Meetings with full Roadmap Committee

- National Science Foundation (US) --Beverly Berger
- INFN (Italy) --Benedetto D’Ettorre
- CNRS (France) --Stavros Katsenevas
- STFC (UK) --John Womersley

Meeting with individual committee members

- Japan- Ministry of Education, Culture, Sports, Science and Technology (MEXT)
- Australian Research Council

(Others contacted

- e.g. NASA, ESA)

Community input

Essential part of process.

- What did we do?
  - Had a dedicated session at LSC/Virgo Collaboration meeting in October 2007
  - Talk at Elba GWADW Workshop-- May 2008
  - Talk at LISA Symposium-- June 2008
  - Letter to community inviting input, ideas, comments, etc.- wiki set up for e-mails from community--

    gwicpoll@ligo.caltech.edu

  - Roadmap members were asked individually to actively solicit input from the communities they represented

Status

- Complete!
- 2 piece document
  - Short executive summary and recommendations (13 pages)
  - Full roadmap document (~108 pages)
- Formatting being finalised
- Will be released on to GWIC website *very* soon
- Preview in this presentation

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EXECUTIVE SUMMARY

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EXECUTIVE SUMMARY

Introduction

Gravitational wave science is on the verge of direct observation of the waves predicted by Einstein's General Theory of Relativity and opening the exciting new field of gravitational wave astronomy. In the coming decades, ultra-sensitive arrays of ground-based instruments and complementary spaced-based instruments will observe the gravitational wave sky, inevitably discovering entirely unexpected phenomena while providing new insight into many of the most profound astrophysical phenomena known. This new window into the cosmos could revolutionize humanity's understanding of the Universe in which we live.

Recognizing that the field has approached this historic moment, in July 2007 the Gravitational Wave International Committee (GWIC) initiated the development of a strategic roadmap for the field of gravitational wave science with a 30-year horizon. The committee was made up primarily of members of GWIC with representation from the ground and space-based experimental gravitational wave communities, the gravitational wave theory and numerical relativity communities, the astrophysics components of the gravitational wave community and major projects and regions participating in the field world-wide. The committee sought and received advice from many experienced practitioners in the field, as well as a number of highly regarded scientists outside the sphere. Input was also sought from the many funding agencies that support research and projects related to gravitational wave science around the world

The goal of this roadmap is to serve the international gravitational wave community and its stakeholders as a tool for the development of capabilities and facilities needed to address the exciting scientific opportunities on the intermediate and long-term horizons.

Science Goals

The future development of the field should be driven by maximizing the discovery potential and subsequent exploitation of the field of gravitational wave observations. Gravitational wave detectors will uncover new aspects of the Universe by helping us to study sources in extreme physical conditions: strong non-linear gravity and relativistic motion, extremely high density, temperature and magnetic fields. Because of the very weak nature of gravity and lack of dipole radiation, the efficiency of converting mechanical energy in a system into gravitational radiation is very low and thus it is the signals produced by astrophysical systems, where there are potentially huge masses accelerating very strongly, that are of the greatest interest. Gravitational wave signals propagate essentially unattenuated and are expected over a wide range of frequencies, from 10-17 Hz in the case of ripples in the cosmological background, through 103 Hz when neutron stars are born in supernova explosions, up to possible signals at GHz from processes in the early Universe, with many sources of great astrophysical interest spanning this range in between, including black hole interactions and coalescences, neutron star coalescences, low-mass X-ray binaries such as Sco-X1 and rotating asymmetric neutron stars such as pulsars.

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By observing the rich variety of signals from these sources our goal is to answer key scientific questions in:

Fundamental physics and general relativity

- What are the properties of gravitational waves?
- Is general relativity the correct theory of gravity?
- Is general relativity still valid under strong-gravity conditions?
- Are Nature's black holes the black holes of general relativity?
- How does matter behave under extremes of density and pressure?

Cosmology

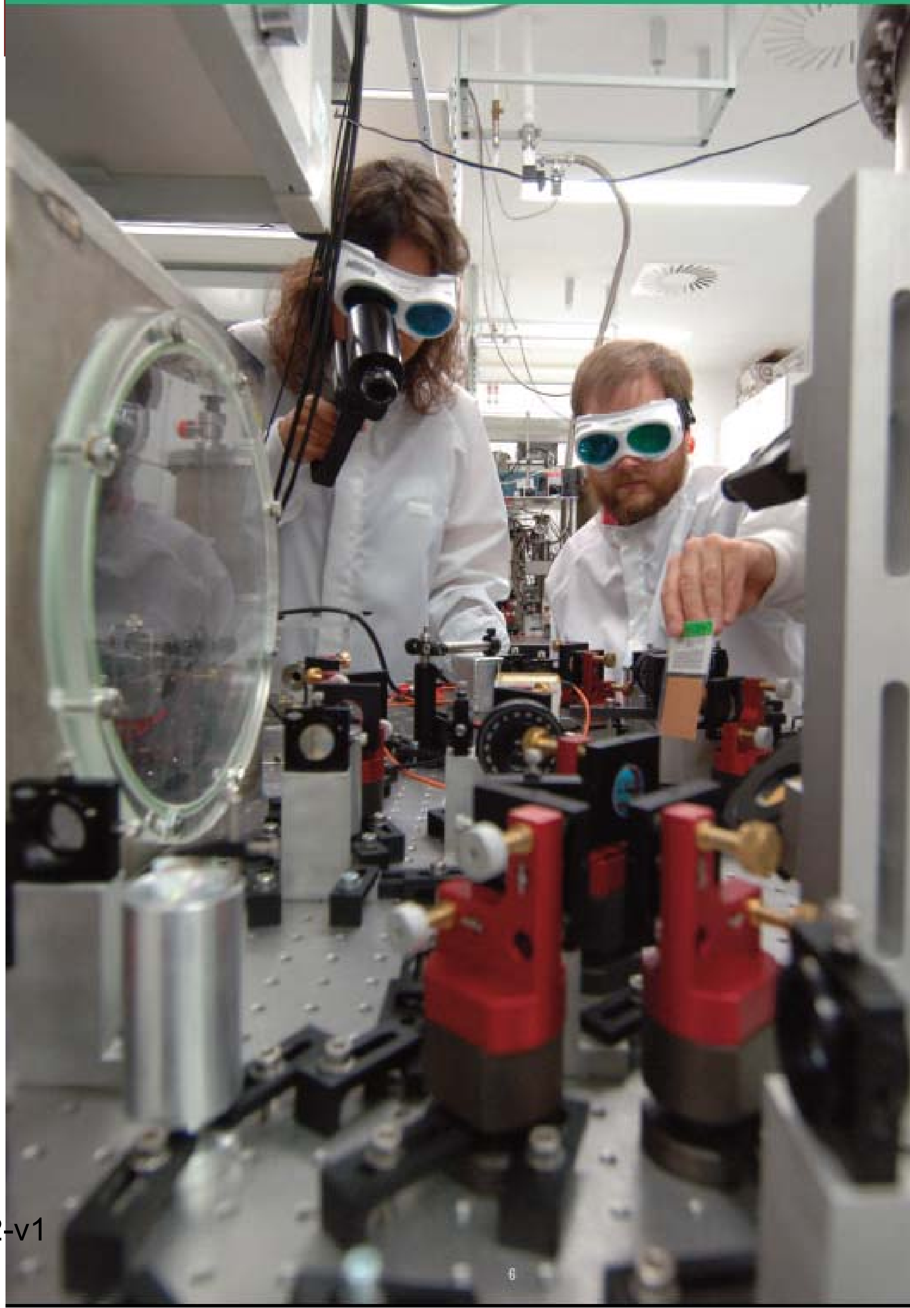
- What is the history of the accelerating expansion of the Universe?
- Were there phase transitions in the early Universe?

Astronomy and astrophysics

- How abundant are stellar-mass black holes?
- What is the central engine behind gamma-ray bursts?
- Do intermediate mass black holes exist?
- Where and when do massive black holes form and how are they connected to the formation of galaxies?
- What happens when a massive star collapses?
- Do spinning neutron stars emit gravitational waves?
- What is the distribution of white dwarf and neutron star binaries in the galaxy?
- How massive can a neutron star be?
- What makes a pulsar glitch?
- What causes intense flashes of X- and gamma-ray radiation in magnetars?
- What is the history of star formation rate in the Universe?

The GWIC Roadmap Committee has identified a set of recommendations that address specific short-term activities that GWIC and the gravitational wave community should undertake to enhance progress towards the most important goals of this roadmap or to improve the focus of the field on key scientific and technical issues.

This roadmap will serve the international gravitational wave community and its stakeholders as a strategic tool in planning for the development of capabilities and facilities needed to seize the tremendous scientific opportunities now on the horizon. This material represents the consensus best judgment of many of the leaders in the field and is endorsed by the gravitational wave community. Ideally the future development of gravitational wave astronomy will follow the overall direction presented herein so that the great discoveries possible with gravitational waves will become a reality.



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Ground-based detectors

Recent years have seen a shift in the technologies used in gravitational wave searches, as the first generation of large gravitational wave interferometers has begun operation at or near their design sensitivities, taking up the baton from the bar detectors that pioneered the search for the first direct detection of gravitational waves. These ground-based km-scale interferometers and their advanced upgrades will be critical in establishing the field of gravitational wave astronomy through the detection of high luminosity gravitational wave sources such as the merger of binary neutron stars and black holes.

In the US, the Laser Interferometer Gravitational-wave Observatory (LIGO) consists of three multi-kilometer scale interferometers, two in Hanford, Washington, and one in Livingston, Louisiana. In Europe, Virgo is a multi-kilometer scale interferometer located near Pisa, Italy, and GEO600, a kilometer-scale interferometer, is located near Hannover, Germany. The TAMA detector, located near Tokyo, Japan, is half the size of GEO600. It is hoped that the first direct observation of gravitational waves will be made in the next few years by an inter-national network consisting of these detectors.

Major upgrades of LIGO (Advanced LIGO), Virgo (Advanced Virgo) and GEO600 (GEO HF) will be completed in the next half decade resulting in a network with the sensitivity needed to observe gravitational wave signals at a monthly or even weekly rate. To fully capitalize on this important scientific opportunity, a true global array of gravitational wave antennae separated by continental distances is needed to pinpoint the sources on the sky, and to extract all the information about each source's behavior encoded in the gravitational wave signal. In the medium term, this means the first priority for ground-based gravitational wave detector development is to expand the network, adding further detectors with appropriately chosen intercontinental baselines and orientations to maximize the ability to extract source information.

The most advanced plans along these lines are with the Japanese Large-scale Cryogenic Gravitational-wave Telescope (LCGT) and the Australian International Gravitational Observatory (AIGO). Possibilities for a detector in India (INDIGO) are also being studied. A continental scale network made up of advanced interferometers in the US, Europe, Asia and Australia would provide an all-sky array that could detect, decode and point to the sky-position of gravitational wave sources in the audio bandwidth where many of the most interesting sources are located.

Recommendation - We recommend that GWIC sponsor a series of workshops, each focused on the status and development of a particular critical technology for gravitational wave instruments. These workshops will help promote exchange of ideas, provide visibility and encouragement to new efforts in critical areas of technology development, and help bring to bear the combined resources of the community on these problems

Recommendation - We recommend that GWIC organize a workshop to elucidate the scientific benefits of interferometers in Japan, Australia and possibly India, as a way to encourage further international support and recognition of the potential scientific contributions of these facilities as part of the global network of ground-based gravitational wave detectors.

There is a great opportunity to further expand and improve the capabilities of this ground-based network in roughly the next 15 years by developing underground interferometers with even better sensitivity particularly at low frequency. Such underground detectors would operate together with Advanced LIGO, Advanced Virgo, LCGT and AIGO following enhancements to these advanced instruments.

Successful deployment of third generation, underground gravitational wave instruments will require development of a number of new technologies by the gravitational wave community. Many of the necessary R&D programs take place in a small number of places and with limited coordination and communication. It is important that these developments are well understood by the rest of the community and that additional efforts take place in other regions of the world so that robust technologies are ready when required for the third-generation facilities.

Recommendation - We recommend that GWIC sponsor a series of workshops, each focused on the status and development of a particular critical technology for gravitational wave instruments. These workshops will help promote exchange of ideas, provide visibility and encouragement to new efforts in critical areas of technology development, and help bring to bear the combined resources of the community on these problems

The most advanced concept for an underground low frequency detector is the Einstein Telescope (ET) project. A conceptual design study for ET was funded by the European Commission beginning in 2008 to assess the feasibility of an underground detector to have high sensitivity below 10 Hz. Construction of ET could begin as early as 2017, with commissioning in 2022. Similarly, there is the possibility for a high-sensitivity large-bandwidth detector to be built in the US, potentially in the Deep Underground Science and Engineering Laboratory (DUSEL).

Recommendation - We recommend that GWIC work with the international ground-based gravitational wave community to plan how to optimize the scientific capabilities of a future third-generation network. Specifically, GWIC, in collaboration with any design study groups in the various regions and countries, should organize meetings to assist the community to understand and establish science-driven requirements (e.g. frequency range, sensitivity), possible interferometer designs and configurations, technologies, optical layouts, site configurations and orientations, etc. that would optimize the scientific potential of the network.

Recommendation - We recommend that GWIC establish an international steering body to organize workshops, and promote coordinated R&D efforts in collaboration with existing design study teams to help achieve the goal of an optimized third-generation network.

Recommendation - We recommend that GWIC endorse the scientific importance of the Einstein Telescope and encourage the next steps needed to allow construction of ET to begin in the 2016/17 time frame soon after the expected first gravitational-wave discoveries have been made, and the technology development for ET well understood.

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8 Recommendations to GWIC to guide the development of the field

"The GWIC Roadmap Committee has identified a set of recommendations that address specific short-term activities that GWIC and the gravitational wave community should undertake to enhance progress towards the most important goals of this roadmap or to improve the focus of the field on key scientific and technical issues. This chapter provides the context or background for each of these recommendations and the recommendations themselves."

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8 Recommendations to GWIC to guide the development of the field

8.2 Completion of the second-generation global network

"Background—robust ground-based gravitational wave astronomy based on the projected capabilities of second generation interferometers (e.g. Advanced LIGO and Advanced Virgo) requires a fully global array of instruments spaced at continental distances to provide good pointing accuracy over the whole sky. Therefore, instrumentation of comparable sensitivity to Advanced LIGO and Advanced Virgo is highly desirable in the Southern Hemisphere and in Asia.

We therefore emphasize the importance of implementing interferometers with sensitivity comparable to Advanced LIGO and Advanced Virgo, in both Asia and in the Southern Hemisphere. It is essential for the field that these instruments become operational relatively early in the observational lifetime of Advanced LIGO and Advanced Virgo."

Recommendation—We recommend that GWIC provide the forum where international support for efforts to bring about such instruments in Japan, Australia and possibly India, can be coordinated and where the community can work together with the proponents to ensure that the siting, design, orientation, etc. of such instruments is carried out to optimize the scientific capabilities of the global network.

Recommendation—We recommend that GWIC organize a workshop to elucidate the scientific benefits of interferometers in Japan and Australia as a way to encourage further international support and recognition of the potential scientific contributions of these facilities as part of the global network of ground-based gravitational wave detectors.

8 Recommendations to GWIC to guide the development of the field

8.3 Gravitational Wave Detectors in Space

"Background—The range of frequencies from 0.1 Hz down to 1 / (age of the Universe) offers some of the most spectacular gravitational wave science. The scope of gravitational signals comprises mergers of supermassive black hole binaries, extreme mass ratio inspirals into massive black holes, galactic binaries, stochastic backgrounds from the early Universe and quantum fluctuations after the big bang. Ground-based detectors will never be sensitive to gravitational waves with frequencies below about ~ 0.1 Hz because of the unshieldable background of terrestrial gravitational noise.

Detection technologies at these frequencies are diverse and range from pulsar timing and large baseline laser interferometry through spacecraft tracking to polarization measurements of the cosmic microwave background. All of these technologies will eventually be used to observe the complete gravitational wave spectrum covering more than 20 orders of magnitude in frequency. LISA, a space-based interferometer funded by NASA and ESA will open the low-frequency gravitational wave window from 0.1 mHz to 0.1 Hz. The goal of a launch of LISA in 2020 is technologically feasible and entirely timely, considering that the technology precursor mission LISA Pathfinder will launch in 2011."

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8.3 Gravitational Wave Detectors in Space

"DECIGO is a space-based mission under consideration in Japan to explore the gravitational wave window from 0.1 to 10 Hz. The DECIGO Pathfinder mission is expected to be launched in the early-to middle part of the next decade. The DECIGO Pathfinder was recently selected as one of the five important mission candidates for the small-science satellite series run by JAXA/ISAS.

Technology development for post-LISA missions should be planned to make a smooth transition into the routine multi-wavelength gravitational wave astronomy that is certain to develop after the first detections have been made by LISA and advanced ground-based detectors. Technology development for such mission should be pursued in a timely manner. Any undue delays would push back the time-scale for post-LISA missions."

Recommendation—We recommend that GWIC support the gravitational wave community in setting the launch of LISA in 2020 to open the low-frequency window from 0.1 mHz to 0.1 Hz, as the highest priority for a space mission.

Recommendation—We recommend that GWIC endorse the importance of a timely start for technology development for LISA follow-on missions and communicate this to the appropriate funding agencies.

8 Recommendations to GWIC to guide the development of the field

8.4 Theory, Data Analysis and Astrophysical Model Building

"Background— To fully exploit the scientific potential of gravitational-wave observatories will require the ability to analyze and interpret the data obtained. To accomplish this, a continuing collaboration among data analysts, astrophysical theorists, and analytical and numerical general relativists will be essential. Continuing interactions between these theoreticians and the instrument builders will also be important. Because many of the most important sources of gravitational radiation involve strong-field dynamical general relativity, large scale, high-performance numerical computations will continue to play a critical role."

Recommendation—We recommend that GWIC support and advocate for a strong and ongoing international program of theoretical research in general relativity and astrophysics directed toward enabling a quantitative understanding and interpretation of gravitational-wave signals.

8 Recommendations to GWIC to guide the development of the field

8.5 Toward a third-generation global network

“Background— The scientific focus of a third-generation global network will be gravitational wave astronomy and astrophysics as well as cutting edge aspects of basic physics. Third-generation underground facilities are aimed at having excellent sensitivity from ~1 Hz to ~10^4 Hz. As such, they will greatly expand the new frontier of gravitational wave astronomy and astrophysics.

In Europe, a three year-long design study for a third-generation gravitational wave facility, the Einstein Telescope (ET), has recently begun with funding from the European Union. In order to optimize the scientific contributions of the third-generation network it will be important that the network as a whole (including the second-generation instruments) constitute a well-conceived global array that is optimized to provide the best science. This will require coordination and collaboration by the designers of third-generation facilities across the globe taking into account the capabilities of the second-generation facilities.”

8 Recommendations to GWIC to guide the development of the field

8.5 Toward a third-generation global network

Recommendation—We recommend that GWIC work with the international ground-based gravitational wave community to plan how to optimize the scientific capabilities of a future third-generation network. Specifically, GWIC, in collaboration with any design study groups in the various regions and countries, should organize meetings to assist the community to understand and establish science-driven requirements (e.g. frequency range, sensitivity), possible interferometer designs and configurations, technologies, optical layouts, site configurations and orientations, etc. that would optimize the scientific potential of the network.

Recommendation—We recommend that GWIC establish an international steering body to organize workshops, and promote coordinated R&D efforts in collaboration with existing design study teams to help achieve the goal of an optimized third-generation network.

Recommendation—We recommend that GWIC endorse the scientific importance of the Einstein Telescope and encourage the next steps needed to allow construction of ET to begin in the 2016/17 time frame soon after the expected first gravitational-wave discoveries have been made, and the technology development for ET well understood.

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8 Recommendations to GWIC to guide the development of the field

8.6 Development of key technologies for third generation ground-based instruments

"Background — Successful deployment of third generation, underground gravitational wave instruments will require development of a number of new technologies by the gravitational wave community. The use of cold test masses and associated cryogenic technology with its pumps, moving cryo-fluids and other possible sources of mechanical noise is extremely challenging. Development of low loss coatings will require a major systematic program of sensitive measurements. "Squeezing" and other techniques for manipulating the quantum properties of light are still primarily pursued in small scale laboratory environments. Many of these (and other) development programs take place in a small number of places and with limited coordination and communication.

It is important that these developments are well understood by the rest of the community and that additional efforts take place in other regions of the world so that robust technologies are ready when required for the third-generation facilities."

Recommendation—We recommend that GWIC sponsor a series of workshops, each focused on the status and development of a particular critical technology for gravitational wave instruments. Topics in such a series could include cryogenic techniques, coating development for reduced thermal noise, "Newtonian noise," techniques for quantum noise reduction, and overall network configuration. These workshops will help promote exchange of ideas, provide visibility and encouragement to new efforts in critical areas of technology development, and help bring to bear the combined resources of the community on these problems.

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8 Recommendations to GWIC to guide the development of the field

8.7 Outreach to the Astronomy community

“Background— A critical goal for the field in the coming decade is to develop close ties with astronomy so that the scientific use of gravitational wave signals, both by themselves and in concert with other signals (electromagnetic, neutrino) becomes recognized in the future as an important aspect of astronomy. Given the timescale in which gravitational wave astronomy will produce results, we now have an excellent opportunity for our field to foster the interest of the current and coming generations of astronomers and astrophysicists in the scientific potential of our field, as well as communicating the excitement of gravitational wave astronomy to the public.”

Recommendation—We recommend that GWIC plan an outreach campaign focused on engaging public, school and political audiences with the excitement, promise and gains to society of the science and technology of gravitational wave astronomy.

Recommendation—We recommend that GWIC plan an outreach campaign focused on the astronomy, astrophysics and other relevant scientific communities. The primary goal of this campaign would be to engage the interest of such scientists in the work underway in gravitational wave astronomy and astrophysics, and to foster collaboration and scientific exchanges. We recommend, for example, that GWIC encourage and facilitate multi-messenger collaborations between the gravitational wave, electromagnetic and neutrino astronomy communities. GWIC sponsored workshops with attendees from these communities would be an effective step in this direction. The outreach campaign should be developed and organized by a standing GWIC subcommittee.

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8 Recommendations to GWIC to guide the development of the field

8.8 Public release of data

"Background — In the next decade the field of gravitational wave astronomy should become an important component of the worldwide astronomy effort, especially if real integration and synergy with other branches of astronomy can be achieved. This will require our community to move toward a culture more consistent with that of the astronomy community. As such, it will be important for data from gravitational wave instruments to be made available to the scientific community and the public as is now the case for publicly funded astronomical observatories in many countries.

This will require a carefully implemented study on the part of the international gravitational wave community to determine the steps required to meet this goal, the appropriate deliverables, and the effort and cost involved, taking into account the requirements of funding agencies in different countries."

Recommendation—We recommend that GWIC commission a study on the means to best implement the goal of greater availability of data. This study should involve knowledgeable members of the international gravitational wave community as well as members of the astronomy, astrophysics, particle physics and other communities who have experience in this area.

8 Recommendations to GWIC to guide the development of the field

8.9 Continued involvement of the Bar Detector community in the field

"Background— Recent years have seen a shift in the leadership in gravitational wave observations, as the first generation of large gravitational wave interferometers has begun operation near their design sensitivities, taking up the baton from the bar detectors that pioneered the search for the first direct detection of gravitational waves. The current generation of these bar detectors, until relatively recently the main observational instruments, has been surpassed in sensitivity by laser interferometer based detectors capable of extended observations.

Research by the bar detector groups has not yet identified a clear path toward future sensitivities which can compete with the interferometric detectors. As a result, the supporting agencies have begun to limit or reduce the funding for bar detectors"

Recommendation—We recommend that, when the present astro-watch phase is completed, other projects in the gravitational wave community encourage scientists from the bar detector community to join the ongoing detector projects. The expertise of the bar detector scientists in ultra-sensitive measurement technologies and data analysis is a valuable resource and should be retained within the gravitational wave community.

What happens now?

- The formatted Executive Summary and full Roadmap will be made publicly available on the GWIC website
- Printed glossy versions are also being produced
- The community will be informed through
  - Presentations, eg:
    - Here,
    - Jay Marx: Fujihara seminar, Japan, 27th May 09
    - Sheila Rowan: Amaldi meeting, US , 22nd June 2009
  - direct communications from GWIC to the communities it represents
- The Roadmap will be officially presented to GWIC at the GWIC meeting immediately prior to the June Amaldi meeting in New York

- GWIC will then discuss
  - what impact we want this to have on funders? Our field? Other scientists?
  - what plans it can implement to respond to the roadmap recommendations re: promoting the goals of the field
  - how to get further good community input to, acceptance of and advocacy of the roadmap goals
  - how to take account of changes in the field when they happen and keep the roadmap relevant
  - whether an annual review of the roadmap by GWIC is appropriate