Thoughts on the Need for Coordinated R&D for Future Generation Ground-based Detectors

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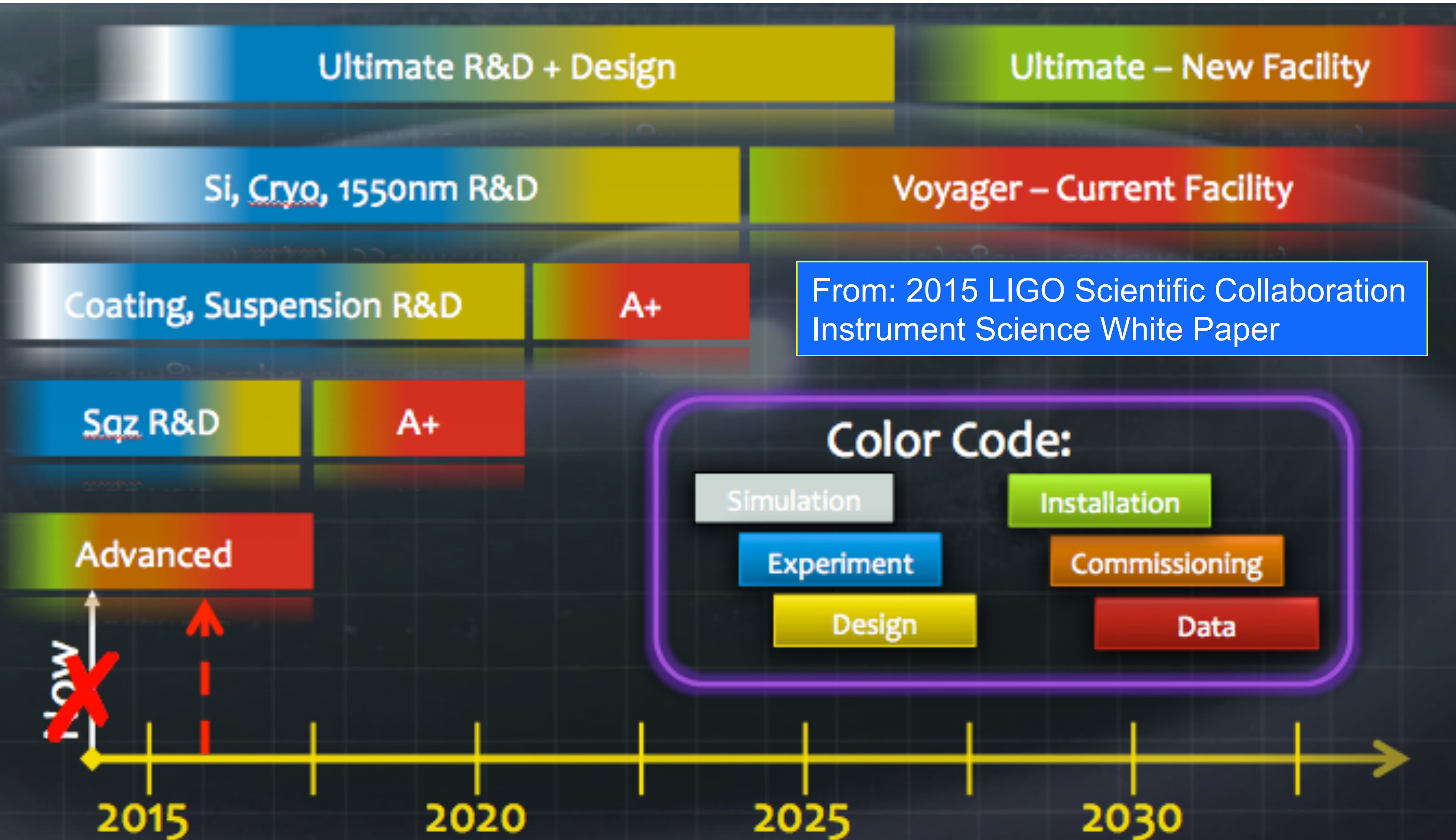
The Post-Detection Terrain

- GW150914 has opened the door to GW astronomy
  - Surprising to most (all?) how quickly it happened
  - Surprising to many that it was a binary black hole merger
- That one detection has informed the GW science case for next gen detectors
  - We now know that the universe contains BBHs → low frequency matters!
  - We still want to detect binary neutron stars, NSBH, galactic supernovae, isolated pulsars and NS → mid and high frequencies matter
- Multi-messenger astronomy is another key science goal
  - Must be taken into consideration when designing 3rd generation detectors
    - Topologies and site location
- ***The case for proposing upgrades to existing facilities and new facilities housing 3G detectors is both strong and urgent!***
  - *In the past, there have been long gestation periods for GW detectors*

'Current versus Future Facilities' versus 'Current & Future Facilities'

- Start with rough estimates of the costs
  - **Engineering Estimate:** Upgrades of two detectors in current facilities: $150M (in 2016 $)
  - **Guess:** New facilities with new detectors: Much more!
- Exploiting sensitivity limits of current facilities (including facility modifications) is *by far* the lower cost option
  - Supports a '3X' improvement using current LIGO facilities
  - Caveat: LIGO Observatories are showing signs of aging and will likely need a substantial refurbishment of the vacuum system in the next 5 years
- A new 'CE-class' observatory with 10 or 20 or 40 km arm lengths will require a new site
  - Both Hanford and Livingston are constrained by local development, land ownership, environmental constraints
  - Neither the Hanford or Livingston sites are 'great' from an environmental standpoint (seismic, wind, …)
  - Land acquisition issues may ultimately force the US detector to go underground

Time Scales



From: 2015 LIGO Scientific Collaboration Instrument Science White Paper

Prerequisites for funding a US 3G detector

- *Essential* Advanced LIGO must reach its design sensitivity
  - #1 -- because it provides proof that we understand and can tame the noises in 2G interferometers
  - #2 -- it will demonstrate to funding agencies that we can deliver on our design goals
- *Essential* The science case for 3G detectors must be extremely well developed given what we know at the time of the proposal
- *Essential* The community will have to prepare their respective funding agencies that big projects are being planned
  - It can take 5 years to get a project 'queued up' into the NSF Major Research Equipment and Facilities Construction budget
- *Essential (for Cosmic Explorer)* An external evaluation must be conducted by a panel of experts
  - Is the science case sufficiently strong for a 3G detector?
  - Is the technology development mature?
  - Is their preliminary costing and project planning, or is there a path to those?
  - ….
- *Nice to Have* International planning and coordination
  - May be essential for CE-class project
- *Nice to Have* Support and advocacy from an outside community
  - They support GW science because it adds to their science
  - For the GW community, it's the astronomers, perhaps nuclear physicists

Considerations in formulating the Global 3G Network

- First generation GW interferometers were independently designed and constructed
  - LIGO, Virgo (joint French, Italian), GEO (joint German, UK)
  - We were competitors at the time
- Second generation GW detectors had some elements of coordination …
  - Advanced LIGO had US, UK, German, Australian contributions
- … but by and large were independently designed and built
- We now collaborate on the analysis of GW data
  - LIGO-Virgo agreement (2007), LV pre-agreement (2013)

- **For 3G, the GW community intends to 'go big'**
- The scale of the project (at least two 10+ km class interferometers) may require coordination across collaborations/projects to take advantage of 'economies of scale'
- Advantages of coordination
  - (At least partial) homogeneity in design and construction
  - Coordinated site selection for optimal network design
  - Makes best use of distributed expertise
- Disadvantages of (or perhaps better stated challenges in) coordination
  - Requires establishment of robust management structure, necessitating giving up some control by partners
  - Requires robust system engineering, establishment of standards, interface control, quality assurance program, …
- ***Major challenge may be synchronization of US/European/Japanese plans for 3G upgrades***

Coordinated R&D Among the Projects

- R&D themes are common for ET/Cosmic Explorer and Voyager
  - Lower loss coatings
  - Si test masses
  - Longer wavelength stabilized lasers
  - Cryogenics
  - Newtonian Noise
  - Control schemes
  - …
- Currently, the major projects/collaborations do not really ‘inter-collaborate’ on R&D
  - LSC, Virgo, KAGRA each have separate R&D programs; some cross-talk, but little to no coordination
- ‘Coordination’ here is defined as having a common program in which resources (= expertise, person power, funding) are assigned and managed efficiently
  - LSC Instrument Science White Paper is probably the best example of a coordinated R&D effort
- Distinction between ‘R’ and ‘D’ in this model?

Agency Coordination

- In the US, agencies (NSF) follow scientific community desires …
- … subject to boundary conditions
  - Boundary Condition #1: available agency budgets and budget projections (dictated by US Congress)
  - Boundary Condition #2: agency priorities (eg, applied vs fundamental science)
- NSF has established the Gravitational Wave Agency Correspondents group to lay the groundwork for establishing coordination among agencies that support ground-based GW research
  - ARC (Australia), CFI (Canada), CNRS (France), CONACYT (Mexico), DFG (Germany), INFN (Italy), NASA (US), NSF (US), STFC (UK)
  - Indian DAE membership pending
  - A working group, ie, no Directors, Presidents, Lab Directors
  - This group has only met once, primarily to introduce themselves
- My impression: the GWAC is 'standing by' to respond to community driven inputs and 'pushes'

Roundtable discussion topics

- Do we believe that a global R&D coordination is necessary for the 3G network? If yes, what kind a model would you envision for that coordination, and on what time scales
  - Two examples might be ‘loose’ (= R&D based on a collaborative approach such as is carried out in the LSC) to ‘tight’ (= a tightly coordinated R&D program with central management and coordinated agency-level funding support).
- How soon does the 'roadmap' need to be frozen for seriously moving forward a 3G network (where network means two or more new GW facilities of the CE/ET class) to be operational sometime on the year ~ 2030 time scale?

Roundtable discussion topics (II)

- What is the best scientific tradeoff between data taking and taking LIGO down for a major Voyager upgrade?

- What role should GWIC play in enabling/fostering coordination?

- What else?

Panel: Lisa Barsotti, Federico Ferrini, Gabriela Gonzalez, David McClelland Shinji Miyoki, Michele Punturo, Sheila Rowan, David Shoemaker

Overarching goal of this roundtable

1) Determine if a reasonable consensus exists on what 'coordination' means, and from that establish what level of coordinated R&D should be done within the community.

2) Discuss steps needed move forward, as well as relevant time scales for those steps.

In a perfect world, we would come away with a framework that can be discussed at the 'Dawn II' workshop taking place on July 7,8 in Atlanta, GA and the GWIC meeting in New York City on July 10.