

DAS SIG REPORT 6/18/2022

Visioning a DAS Facility to Advance SAGE-GAGE Science

June 16, 2022, 10:45 a.m. – 12:15 p.m.

2022 SAGE-GAGE Workshop in Pittsburgh, PA

Description: Rapid growth of DAS applications in geoscience makes it likely that SAGE-GAGE researchers will increasingly employ DAS in projects. DAS technology, optical fiber availability, data management, and data analysis are also changing at a high rate. How might a DAS facility within SAGE-GAGE be designed to promote science initiatives?

DIG Goals: Workshop participants as future users of a DAS facility will provide community input in the form of a short report.

The turnout was modestly strong with an estimated 40-50 participants. The session moderators were Herb Wang (U. of Wisconsin-Madison), Nate Lindsey (FiberSense), Ved Lekic (U. Maryland), and Kent Anderson (IRIS). The audience participation was, however, less than hoped. Based on a show-of-hands, it appears as if a relatively small percentage of attendees at the Workshop were DAS adopters. This perhaps can be a bias that attendees are drawn to the meeting because they are consumers of core SAGE-GAGE facilities, which does not include DAS. In any event, the session consisted primarily of moderators providing information partially guided by questions from the audience. The remainder of the report consists of four summaries that chronologically record the prepared presentations and ensuing discussions. The first is my summary followed by notes from Kent Anderson (IRIS), and Karianne Bergen (Brown), and Xiaowei Chen (OU/Texas A&M. Many thanks to the volunteer rapporteurs whose notes overlap in ways that illuminate the sense of the discussion.

Herb Wang Summary

1. Introduction - Herb presented the session agenda, which became somewhat freeform as the meeting progressed.
2. NSF Perspective - Maggie Benoit was not available. Herb offered up a conversation with her in which she said that initially she was looking for scenarios of what to add/drop in budget scenarios that ranged from increase to flat to decrease. However, input always seemed to avoid the hard question of what to give up. In that vein, DAS proponents can point to the science opportunities and the rapid increase in DAS adoption but not tell NSF what to give up to include it.
3. Summary of AC-GEO report "A Portfolio Review of EAR Seismology and Geodesy Instrumentation" of April 2021.- Ved Lekic presented a set of slides summarizing the report's recommendations that included a fairly high priority for DAS within the context of broader SAGE-GAGE operations.
4. New fiber-optic sensing capabilities on submarine cable – Herb attempted to describe new technologies being reported in peer-reviewed literature on earthquake detection on submarine cables from the metrology (Marra et al., 2018, 2022) and big internet technology (Zhan et al., 2021) communities.

5. Nate provided a start-up company's perspective of being at the confluence of the optical communications and fiber-sensing technologies. FiberSense provides DAS surveys to commercial clients. His company acquires data that are not public domain but of potential community value. He raised the interesting question of "What is the value of information"? The unused data might not be proprietary but the additional expense of archiving the data cannot be justified by the client.
6. In response to a participant inquiry about a facility helping investigators locate dark fiber, Herb introduced a slide from his computer sciences colleague, Paul Barford, at the U. of Wisconsin-Madison, which addressed an initiative of public-private partnerships in the form of a community data base of Internet Service Providers (ISPs) willing to provide access to their fiber. He described the U. of Wisconsin-Madison working with a telecom company in Alaska with whom Zack Spica at the U. of Michigan has now set up a DAS monitoring project using remote installation by Aragon Photonics with the IT support of Cordova Telecom Cooperative (CTC). Paul Barford is seeking to organize a workshop bringing together commercial coherent optical communications researchers and geophysicists.
7. Kent provided the IRIS perspective on what they are set up to do and how they already serve the community via instrument pools at PASSCAL and Data Management functions. But DAS data sizes are prohibitively large at present and IRIS awaits community guidance. A white paper is being released imminently by the Data Management Working Group of the RCN and a workshop of metadata standards is being planned for Spring 2023.
8. Herb noted that Zack Spica will shortly submit a manuscript to SRL describing PubDAS, a public DAS data archive of a dozen or so data sets to be hosted at the U. of Michigan's HPC. The data will be accompanied by robust metadata.
9. General discussion that followed was captured in the notes by the volunteer rapporteurs Kent Anderson, Xiaowei Chen, and Karianne Bergen.

Kent Anderson Notes

Agenda review

Leaders: Herb, Nate, Ved - NSF not present

Maggie's concerns: with a flat funding scenario, we might have to limit other capabilities to make room for DAS

Ved - perspective on IPRC report regarding DAS

- Potentially fills a gap in time/spatial resolution between seismic and geodetics
- Potential to observe more of the full seismic wavefield over long distances
- Challenges
 - Equipment availability
 - Deployment expertise
 - Data management and processing
- Big concern is zero sum on facility capabilities - must consider impact to existing capabilities as we add more

- What are the costs?
- Full costs for equipment, training, support, logistics, staffing, etc is being developed currently

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Herb - new applications

- Monitoring the “Internet” itself (state of polarization) between LA and Chile -
 - Interpretation of SOP of regular communications can provide rate of strain information
 - Corrections that are applied by telecommunications providers is essentially processed strain data.
 - These are getting dumped on the floor due to its size
 - Zhongwen Zhan et al
- Marra et al.
 - Trans-ocean cable phase corrections are impacted by seismic signals
 - Opportunity to exploit their “noise” (Optical interferometry)
 - Take advantage of inline Fiber Bragg Grating reflectors at amplifiers to discretize spatial sampling
- Need a community forum to discuss emerging technologies and applications

Nate - convergence of geophysicists and photonics engineering communities

- Costs are coming down on and number of vendors increasing (35ish)
- With expanded options, loads more data are available
- Fibersense is providing a data service model from existing global installations
- Need is evolving and there will be a number of new and expanding applications
- This might be very complementary to a community resource for checking out an interrogator/fiber that they can operate for smaller temporary experiments or for educational purposes.

Community/participant comments

- Ann Sheehan - could IRIS take responsibility for finding dark fibers and access points for field experiments?
 - Not likely - expensive and not clear on usage at this point
 - More likely - collect best practices on working with local providers
- Zhigang Peng - IRIS got the node groups kicked off by facilitating a node owners group. Do you see doing this for DAS groups
 - Yes - very similar situation as this capability evolves

- USGS guy (Andy Barbour?) - nodes and DAS are quite compatible, so would not like to see nodes sacrificed to support DAS investments.
- Data download fees could be significant as we look at how data usage models change
- Zhigang - how will metadata be collected?
 - Example data sets - look at current standards
 - Whitepaper on metadata and workshop in process.
 - Workshop next spring (2023)
 - Contact Rob Mellors for input and response to whitepaper

Karianne Bergen Notes

- **[Herb Wang]** What do you want to give up? What do we vote off the island? – instead focus on what we gain, leave what to get rid of to the program managers
- **[Ved Lekic]** Portfolio review, like they do in astronomy (nsf.gov/geo/advisory)
 - Scientific Qs from “Earth in Time” report from NAS – where can DAS be helpful?
 - What is an earthquake?
 - Cross shoreline, sensitivity to long periods
 - Respond to earthquakes, e.g. induced seismicity
 - Water cycle
 - Provide dense and continuous monitoring of groundwater changes
 - Hazards
 - Earthquake and tsunami early-warning
 - Can DAS fill the big gap? (seismo-geodetic gap)
 - Challenges: training scientists in new technology, reproducibility of science, extremely large DAS datasets, single-channel
 - **Audience Q:** how deeply did the committee look at costs?
 - A: not that much, we decided it wasn’t our job (looked at different scenarios), hard to do without a specific proposal / hard to cost out something that doesn’t exist yet (e.g. training, long-term maintenance, etc.)
 - [Herb Wang] get directional sensitivity using spokes-design or other geometries; DAS is true array in terms of timing – important feature
- **[Herb Wang]** Opportunities from submarine cable
 - Zhongwen Zheng et al paper

- Internet photonic sensing; network scientists correct for polarization (synchronized in time), monitor phase with DSP to make the correction – that’s the information seismologists want
- Marra et al. paper
- Optical interferometry: telecom industry wants to monitor cables – look at every 45kn segment as a submarine sensing interval (localize by triangulation)
- **Discussion Q:** Who is going to keep track of these technologies? Keep these communities connected?
- **[Nate Lindsey]** convergence between photonic optical engineers and geophysicists
 - 7% of the time cables fail because of a geophysical event (e.g. submarine landslide, underwater eruption)
 - DAS interrogators are \$\$\$ (~\$120k) -- now many companies
 - FiberSense – DAS data as a service, scientific partnerships
- **Audience Comment [Kent Anderson (IRIS/PASCAL program manager)]:** What are specific applications and user community desires? Happy with DAS as a service? What’s the feel of the potential users of what you’d like to see as NSF-funded community resource?
 - **Audience A:** Could one of the services be identifying dark fiber?
 - **[NL]** Lots of off-shore cables (dark fiber in those cables), thinking of those as instruments and having a way to get in contact to get that set up – those pieces need to be layered into facility
 - Potential IRIS service: Collecting best practices for identifying dark fiber
 - **[Zhigang Peng]** Form network of people who already have resources? Facilitating discussions.
 - **Audience comment:** Don’t get rid of nodals in favor of DAS – benefit to collocated nodals & DAS
 - **Audience comment:** start working with small datasets because lacking infrastructure to deal with large datasets
- **[Herb Wang]** Instrumentation support side & data side
 - Internet Atlas with CS faculty– mapping physical internet structure (map of internet cables)
 - Q: how can we take advantage of deployed internet infrastructure? A: public/private partnerships
 - Database – which telecom companies can you go to for internet photonic sensing in a particular region?
 - Risk to telecom companies to let you use their cables
 - IRIS needs funding to keep up with these frontier areas, stay current with these technologies

- **[Nate Lindsay]** Optical Fiber Communication conference
 - Added workshop on submarine sensing – e.g. can you record an earthquake
 - Useful: Putting a value on the records that IRIS is keeping and making available (free to download a seismic waveform from IRIS)
 - **Kent Anderson:** cloud solutions involve costs – who will pay the costs associated with downloading? the user? cost model flipping; how to maximize reuse value/minimize costs per user?
- **[Zhigang Peng]** How do you keep track of metadata?
 - Zack Spica: soft opening for “PubDAS” at UMichigan, about 10 datasets and metadata
 - **Kent Anderson:** Working group on metadata

Xiaowei Chen Notes

Ved, AC-GEO, portfolio review of EAR seismic/geodesy instrument. How DAS fit in this community.

- Can DAS help fill the gap between seismic and geodetic gap.
 - Earthquake – respond to small earthquakes, cross the shoreline, measure full earthquake cycle, sensitivity at long period (??? Not sure about DAS)...
- Water cycle.
- Hazard. Earthquake and tsunami early warning

Examples of DAS data online, like DOE data center. Committee is excited about DAS possibility, but with challenges.

Question about the report for NSF geophysical facility review.

How deeply did the committee look into cost? – not that deeply, committee decided that it was not their job to evaluate. Replacement cost for existing facility can be predicted, cost for something doesn't exist is a bit difficult to predict without an actual proposal. A shallow geophysical facility is being considered.

Disadvantage of single component. Planning new facilities, they can plan different linear arrays to have directional sensitivities. DAS is really advantage for large linear array with high spatial resolution that has synchronized time.

Geophysicists are starting to understand the fiber and crosses the boundary with optical engineers. There are more DAS companies now, and the cost is reducing. What's the value of the interrogator? The commercial aspect of this is that geophysicists can generate data product that is useful for the city or the fiber company itself to protect their cables.

Rapid deployment – installation is easy, permitting is a problem. FiberSense is trenching the road in rural area in Australia to make a grid. Dark fiber scales existing infrastructure.

Kent Anderson looks at the NSF report. Look at the user community desire. Capability for the community for the scientists to check out and learn themselves.

Question: could provide the service to identify dark fiber. Could be an important issue for the future and could be a service to provide. Thinking of these cables as instruments. Lots of details to set up to instrument facilities.

Question: a few years ago, IRIS was involved to identify groups who own nodes. Maybe IRIS could organize groups who own DAS, maybe people have already organized together. Passcal could collect information.

Question: benefits of DAS are amplified with collocated nodal instruments.

Question: do small set of data, look later to expand to larger dataset.

Concerns about the incentives for the two communities to come together.

Data management: putting the value on the waveform record.

Value of the information itself and the speed of the information transfer. Cost recovery and data management. – extremely large dataset, who pays the cost for cloud or storage facility? How to distribute the cost over multiple uses.

How to keep the meta data and keep track of things. Zack is to submit a note about public DAS dataset he organized. Maintain standard about the metadata.

Working group on metadata.