Incorporated Research Institutions for **Seismology**

In the first of two interviews, **David Simpson**, President of the IRIS Consortium, draws upon the successes of one of the country's leading seismology organisations. Supporting both national and international research endeavours, IRIS is confident it has the data and tools to help assess future seismic hazards

Firstly, could you introduce the work carried out by the Incorporated Research Institutions for Seismology (IRIS)? What were the reasons behind its formation?

In the early 1980s the infrastructure for global observations of earthquakes was decaying. Instruments that had been in use since the 1960s, such as analogue photographic recording which collected readings once a day and shared information by post or telex, were outdated and observation stations were being closed. The quality and density of observations greatly limited the research community's ability to advance their science and explore the new and exciting ideas about the Earth's structure and origins of earthquakes being proposed as part of the new theory of plate tectonics.

At the same time, new digital recording and sensor technologies were emerging to allow vast improvements in the fidelity of ground motion recordings from local and distant earthquakes. Satellite communications allowed data to be sent from remote locations to national and global data centres in real time while a global network of interconnected digital stations revolutionised the way we gather, manage and analyse data.

The National Science Foundation (NSF) and the National Academy of Sciences encouraged academic seismological experts at US universities to join together to develop a long-term plan for instrumentation and data collection resources needed to advance scientific studies. A consortium of 26 universities joined together in 1984 to form IRIS as a not-for-profit corporation to develop, propose and eventually implement plans that called for a global network of 128 permanent stations, 1,000 portable stations for high resolution studies and a centralised data collection facility to gather, manage and distribute the data. The Consortium is governed by representatives of member universities, funded by the NSF and works in close collaboration with the U.S. Geological Survey (USGS), other US agencies and many international partners.

All of the programmes were firmly established by the early 1990s. By then, the Global Seismographic Network, operated in collaboration with USGS, had become an important contributor to global earthquake monitoring and research and was setting the standard for similar developments in other countries. The Program for Portable Array Seismic Studies of the Continental Lithosphere (PASSCAL) was acquiring instruments for temporary deployments to study Earth structure and earthquake aftershock sequences, such as that following the Loma Prieta earthquake in California in 1989. A nascent Data Management Center in Seattle had acquired the computer and mass store facilities to collect and hold all of the data and make them freely and openly available to anyone, anywhere.

Who is eligible for IRIS membership? What do you offer to your members?

Membership is open to any US academic institution with research programmes in seismology. In any given year, up to 100 scientists from the academic community and government labs provide a pro-bono service on IRIS committees to keep activities on track in responding to the changing needs of the research community.

Membership has grown to 117 full member institutions (representing virtually every US university with significant research programmes in seismology and Earth sciences), 22 Educational Affiliates and 115 Foreign Affiliate organisations. In recent years, IRIS has become increasingly involved in helping developing countries establish expertise and equipment for monitoring earthquakes and assessing seismic hazards in earthquake prone regions.

Can you offer a brief overview of the types of geophysical research you support? Have there been any noteworthy discoveries of late?

IRIS provides the facilities to support research, but does not carry out the research itself. The basic research performed in academic programmes spans almost the complete spectrum of observational seismology and geophysics – the structure, composition and dynamics of the deep Earth and crust; dynamics and deformation of the continents, subduction zones and ocean basins; global distribution of seismicity; origin of earthquakes and the dynamic processes in earthquake rupture; earthquake hazards; petroleum exploration and extraction; and monitoring of nuclear tests.

A few recent noteworthy discoveries are:

- **The rupture processes in great earthquakes.** The spate of large earthquakes over the past five years has caused terrible human tragedies, but has provided seismologists with an unprecedented opportunity to document the processes of faulting. The initial faulting in a great earthquake like Sumatra lasts for minutes and extends for over 1000 km. The waves from the event keep ringing through the Earth for days to weeks afterwards. With the advent of GSN and other modern networks, it has been possible for the first time to observe these massive ruptures with data that remain on scale and with full dynamic capture of the entire faulting process with significant implications for earthquake hazard assessment

- **Episodic slip and tremor.** The NSF-funded EarthScope project (including seismic stations from IRIS's USArray and GPS geodetic observations from UNAVCO's Plate Boundary Observatory) has observed a new type of fault motion called 'episodic tremor and slip' (short burst of motion of a few centimetres over a few days, occurring every 12-14 months, with accompanying increases in background seismic noise). This phenomenon was first observed by researchers in Japan and Canada in the late 1990s from subduction zones where large earthquakes are known to originate. Almost a decade of EarthScope data has clearly shown that these phenomena are a consistent and ongoing part of the deformation process in the Cascadia subduction zone – an area that is capable of producing great ($M>8$) earthquakes, the most recent of which occurred more than 200 years ago. It is still unclear exactly what the underlying processes are – but it has generated strong interest and extensive research that holds promise for unravelling some of the remaining mysteries about how and why great earthquakes occur

- **Ice quakes in Greenland.** GSN data revealed the presence of mysterious, moderate-sized 'slow' earthquakes – events which occur over tens of seconds to minutes rather the few seconds typical of usual events of comparable size. Because they are rich in long period emissions, but very weak in higher frequencies they are detected and catalogued differently. When the events were finally recognised and located, it became clear that most of them originated in Greenland. These events (equivalent to earthquakes of magnitude ≥ 5) have been shown to be related to the rapid movement of large masses of ice during the calving of massive icebergs from Greenland's glaciers. Sufficient data have now been accumulated to show that they occur primarily during the summer melt and that their frequency appears to be increasing. This has significant implications for climate change and the loss of Arctic ice mass

What has been the greatest achievement of IRIS to date?

The ultimate success of IRIS must be gauged by the scientific impact of the facilities we support. Open access to IRIS data and instruments has enfranchised seismological research programmes at a large number of US universities and established a precedent for international sharing of scientific data. The hundreds of peer-reviewed research papers published each year based on the use of IRIS facilities provide strong testimony to the importance of IRIS resources in enabling research at universities and government agencies in the US and throughout the world.

Underlying the ability to achieve these research successes, however, are fundamental changes in the culture of our scientific community. IRIS has demonstrated how a community of scientists can work together to govern and effectively manage complex and high-quality facility programmes and keep them vibrant and responsive to evolving research needs. A culture to open data sharing; international cooperation; collaborative and interdisciplinary experiments; student mentoring – as well as world class science – are all essential components of (and in some cases a result of) this underlying commitment to shared resources and fundamental scientific drivers.

What goals would you like to see IRIS achieve in the future?

After 25 years, IRIS is a mature and successful organisation. One of the greatest challenges for the future will be to sustain that quality and success through demonstrated results and engagement of a new generation of researchers who have a continued commitment to our goals and mission. Many young scientists have grown up in a field in which the resources provided by IRIS have always been available. We must continue to proactively engage and encourage them to take responsibility of the science-driven guidance and leadership that is essential to the health of the organisation.

As our facility and science matures, many of us are committed to using the experience we have gained to improve the earthquake safety of populations everywhere. Through basic education and training, best practice dissemination, collaborative research programme engagement and effective mitigation strategy advice, the university community can help build more resilient communities in earthquake-threatened areas of the developing world. This will require broadening our community's goals, with increased emphasis on applied as well as fundamental science and the cultivation of resources for support that extend beyond the mission of our science agencies. As more and more of the world's population concentrates in fragile urban environments under threat from major earthquakes, there is an increasing responsibility and imperative to engage. It is a challenge that I am confident the research community can respond to with both intellectual and practical return to themselves and others.

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Incorporated Research Institutions for Seismology

In the second installment of a two-part interview, **David Simpson**, President of the Incorporated Research Institutions for Seismology, delves deeper into the structure of the Consortium, elucidating how it serves the global Earth monitoring community in a digital age and encourages the exchange of data

An important part of the Incorporated Research Institutions for Seismology (IRIS) mission is the promotion of collaboration between its members and affiliates for the advancement of geophysical research. By what means is this carried out?

While the primary operational focus is the collection of seismological data, IRIS has become much more than an instrument facility – it has become a focal point for university-based seismological programmes and has helped establish the academic community as a significant contributor to the collection of data for global monitoring. As a consortium of virtually all of the Earth Science research institutions in the US, IRIS can represent the academic community in the development of new initiatives, to strengthen the support for science and argue for the relevance of seismology and its use in hazard mitigation. The fundamental problems of Earth Science require significant synthesis of information and activities from other fields, organisations and institutions. As a founding member of the international Federation of Digital Seismograph Networks (FDSN), IRIS represents the US community in the coordination of global network observations. IRIS strives to work as a representative of the academic community and within the spectrum of federal and international activities in the Earth Sciences, to encourage a culture of open data exchange and to maximise the impact of contributions to global and societal problems.

Perhaps the most successful example has been EarthScope. This programme is a major 15-year undertaking to systematically use the tools of seismology and geodesy to explore the structure and dynamics of the North American continent. In the late 1990s, IRIS and UNAVCO – a consortium similar to IRIS that uses GPS and related technologies to observe deformation of the Earth's crust – brought together researchers from across the university community to develop and implement a plan to install thousands of observation points across the US and in neighbouring parts of Canada. Now in its 10th year, EarthScope has provided data in unprecedented detail on the three-dimensional structure of regions such as the San Andreas system, Basin and Range, High Lava Plain, Cascadia subduction zone, Colorado Plateau Snake River Plain;

Yellowstone hotspot, Rocky Mountain Front and Colorado Plateau. Many of the classic interpretations of these major geologic terranes are being challenged and exciting new ideas are emerging on the underlying causes of plate interactions, continental deformation and the origin of earthquakes and volcanoes. In the near future, the US Transportable Array – one the major EarthScope components for which IRIS is responsible – is expected to transition to Alaska, where it will spend five years observing the harshest and most seismically-active environments in the US.

IRIS is a key partner of the collaborative Global Seismographic Network (GSN), a network of real-time seismological and geophysical sensors. How has the Network been used so far? Who else is involved with the project?

GSN is an excellent example of multiuser, multipurpose, interagency and international science. GSN is a product of interagency support between the National Science Foundation and U.S. Geological Survey (USGS), and relies on numerous international partners in the operation and support of stations through collaboration with FDSN. It was designed as a globally distributed fiducial network, making use of the highest quality, highest fidelity instruments and installations to capture the full range of possible ground motions. As such, GSN provides the foundational data for research studies and finds applications in global earthquake monitoring (it is the primary source of data in USGS's National Earthquake Information Center (NEIC), whose mission it is to report on global and national earthquakes), tsunami monitoring (through the National Oceanic and Atmospheric Administration's Tsunami Warning Centers) and in both research and monitoring of nuclear explosions (3 GSN stations are part of the Primary Network of the International Monitoring System (IMS) of the Comprehensive Test Ban Treaty Organization and 33 stations contribute to the Auxiliary network). GSN data are finding applications in many other interesting and exotic studies such as discovering massive ice-quakes in the glaciers of Greenland and in observing changes in climate by tracking annual and decadal sea state through the influence of ocean waves on background seismic noise.

IRIS actively pursues policies of free and unrestricted access to geophysical data. Why is this so crucial? By what means do you encourage the exchange of data and knowledge?

Seismology is both a global and international science. The Earth is our laboratory and earthquakes occur beneath all continents and oceans. A significant earthquake anywhere in the world can be recorded on our sensitive seismographs. Only through open and international collaboration is it possible to study these global processes. With modern digital data sensors and internet communication, it is now possible for us to collect continuous data from even the most remote stations and bring them all together in one place for analysis, archiving and distribution.

GSN data describing the ground motions at almost all of the more than 150 stations in the network are constantly sent, in real time, to both USGS NEIC in Golden, Colorado and the IRIS Data Management Center (DMC) in Seattle. These data, sampled 20 times per second at each station, arrive within a few seconds at USGS NEIC, where they are used to detect, locate and report earthquakes anywhere in the world. At the same time, IRIS DMC collects and redistributes the data to any interested researchers (or the public) and collates and archives the data for future distribution and use in research projects.

In the past, prior to the ease of digital transmission and distribution, the data collected by many individual networks or researchers were usually 'private bin' and rarely distributed or even tightly guarded for local research projects. By setting the example, showing the scientific value of data merging, and developing standards and techniques to simplify the process, IRIS has become a leader in free and open data sharing, starting within our own university community and gradually convincing other groups both nationally and internationally.

The Education and Public Outreach (EPO) programme at IRIS administers a range of products and activities aimed at improving public understanding of seismology and Earth Science. Could you summarise the programme?

The vision of IRIS EPO is to 'Advance awareness and understanding of seismology & Earth science while inspiring careers in geophysics'. Earthquakes are inherently fascinating to students and the public. Through museum displays, public lectures, posters, online resources and teaching materials, EPO encourages students of all ages to explore where and why earthquakes occur and learn how they help reveal the internal structure of our planet. For example, within a day following the occurrence of a major earthquake, a slide set is prepared and posted on the web to describe the main characteristics of the event and its effects. These are used widely in schools and universities as 'Teachable Moments' to add scientific content to news stories and encourage deeper exploration of the underlying causes and impact of earthquakes. In partnership with programmes in other countries, simple seismographs are provided to high schools to allow students to collect their own observational data and share them with others in the growing global network of 'Seismographs in Schools'. A very successful internship programme selects top undergraduate students from across the country, brings them together at an IRIS facility in Socorro, New Mexico for a week-long training session, pairs them with a research mentor for a summer research project, and supports them in presenting their results at a national science meeting. More than 125 students have participated in the programme over the past 15 years and nearly 90 per cent have gone on to establish careers in seismology or related geosciences.

Could you outline some of the activities of International Development Seismology (IDS)?

IDS is a new activity for IRIS. It emerged out of a growing interest of consortium members to apply the resources and expertise of the IRIS facility, along with the academic and research experience of university researchers, to help solve problems posed by earthquake hazards in the fragile infrastructure of developing countries in earthquake-prone areas. This interest has been especially strong in areas where working contacts with local university researchers have already been established through IRIS-related field programmes using Program for Portable Array Seismic Studies of the Continental Lithosphere (PASSCAL) instruments. Great strides could be made in protecting lives and infrastructure in these areas with improvements in earthquake monitoring – to identify the earthquake hazards – and implementing engineering and construction practices appropriate to mitigating these hazards. Many of the technologies and instrumentation developed by IRIS have now transitioned to the commercial sector and, with proper education and training, are used in local and regional monitoring networks. IDS seeks to develop partnerships with universities and government agencies in these countries to seek the resources to establish networks and, through education and training, help build local capacity to install, operate and maintain viable earthquake monitoring and reporting systems and the associated infrastructure for civil response and mitigation.

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