

IVS Newsletter

Issue 30, August 2011



RFI Between Friends – VLBI in a DORIS/SLR Environment

– Brian Corey & Chris Beaudoin, MIT Haystack Observatory; Bill Petrachenko, NRCAN

A continuing thrust in the space geodetic community is to deploy instruments using different techniques at common sites. While the close proximity (of order 100 meters) of the instruments to each other affords improved inter-comparison tests, it also increases the potential for interference between instruments.

Of present concern to VLBI are DORIS beacons, plus the aircraft surveillance radars used in conjunction with satellite laser ranging (SLR). Their properties are summarized in the table. As can be seen, their frequencies lie close to, or in, the observing windows of both S/X VLBI and broadband VLBI2010 (2-14 GHz).



DORIS beacon at GGAO in Greenbelt, MD.

	DORIS	SLR Radar
Frequency	2.036 GHz	9.4 GHz
Peak power	9.5 W	4 kW
Duty cycle	100%	0.05%
Antenna mount	fixed	steerable
Antenna pattern	~hemispherical	highly directional

An important feature of the VLBI2010 system is frequency flexibility, which allows the observing bands to be moved around easily to avoid regions of persistent radio frequency interference (RFI). But if the RFI is strong enough to drive an amplifier close to saturation, it can degrade the VLBI performance even if its frequency lies outside the observing bands. As a result, neither S/X nor VLBI2010 is immune to interference from DORIS or SLR radar.

A small committee has been set up by the IVS to evaluate the effects of these transmitters on VLBI, and to explore mitigation strategies, if need be, in collaboration with colleagues in the DORIS and SLR communities.

Our work to date has focused on two areas: verifying by measurement that the power

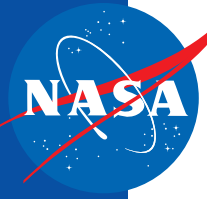
levels received by a VLBI antenna are at the expected levels, and simulating the effect of RFI on broadband VLBI data using realistic models of typical RF electronics. The simulations have shown, for instance, that nonlinear gain effects in the first-stage amplifier cause an SNR loss of more than a few percent when the received RFI power exceeds approximately -70 dBW (100 nW). This loss occurs at all VLBI frequencies, not just at the transmitter frequency.

With the addition of a model for the antenna sidelobe levels (e.g., the ITU-R SA.509 standard), constraints can be placed on acceptable separations and relative pointing directions between the antenna and a transmitter. We find that, with a direct line of sight from an antenna to either a DORIS beacon or a radar 100 m away, significant SNR loss is incurred over unacceptably large regions of the sky.

We are currently exploring options for reducing the strength of the received signal, including placing a barrier to block the line of sight. A barrier must of course not introduce deleterious effects on the performance of either system. Based on preliminary electromagnetic simulations, we are optimistic that mutually acceptable solutions can be found.



Aircraft avoidance radar of NGSRL at GGAO in Greenbelt, MD.



Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California

—An Interview with Chris Jacobs of the Deep Space Tracking Systems Group

The Jet Propulsion Laboratory (JPL) at the California Institute of Technology (Caltech) has been an IVS member since the inception of the service. As an Analysis Center, JPL has contributed to various IVS activities, most recently to the successful creation of the Second Realization of the International Celestial Reference Frame (ICRF2). Newsletter editor Hayo Hase interviewed Chris Jacobs of the Deep Space Tracking Systems group via e-mail to obtain a more thorough picture of what's going on in Pasadena. Chris, thanks for taking the time to answer our questions.



Members of JPL's Deep Space Tracking Systems group (left to right): Michael Kossin, Chris Jacobs, Jim Border, Chuck Naudet, Andres Romero-Wolf, Christina King, and Walid Majid.

Thank you for the opportunity to be interviewed for your IVS newsletter audience. I have very much enjoyed the IVS both for technical enrichment as well as the professional relationships that I've been blessed with.

What are the most important achievements of JPL? What role does VLBI play at JPL?

A little background first: JPL is a hybrid organization. The lab's infrastructure is owned by NASA with the staff hired and managed by Caltech. So we're a government/university hybrid of about 5,000 technical staff. JPL started doing rocket research during the late 1930s. When NASA was founded in the late 1950s, JPL became the lead center for unmanned exploration of the planets. Over the years JPL transitioned away from the propulsion side of space research and more towards the payload instruments. We are probably best known for our flagship planetary missions such as Voyager, Galileo, and more recently the Mars rovers. The next big mission is the Mars Science Laboratory which is scheduled to launch at the end of this year.

Our VLBI effort is much larger than it may appear to the casual outside VLBI observer. We develop all aspects of VLBI. JPL has designers of atomic clocks, antennas, feeds, downconverters, and recording systems. We write software for all stages of VLBI processing: scheduling, correlation, fringe fitting, modeling, and parameter estimation. We support VLBI for the terrestrial frame including earth orientation, the celestial frame, and the planetary ephemeris development. We are focused on supporting deep space navigation of interplanetary spacecraft. Because this work is

literally mission critical with billions of dollars of missions at stake, we have felt it necessary to keep expertise in all aspects of VLBI. For example, there was a stretch a few years back when the international standards for TRF, EOP, and CRF were not all consistently defined. So through that stretch we had to maintain our own internal frames that were consistent with each other.

How did you become a VLBI expert?

I came to California to get my B.S. in Applied Physics from Caltech (1983). After school, I was hired by Arthur Niell into the JPL VLBI group. I learned VLBI on the job from Arthur as well as many others: Jim Williams, Brooks Thomas, Jack Fanelow, Kurt Liewer, Robert Treuhaff, Gabor Lanyi, Chad Edwards, Don Trask, and George Resch. After a few years I found myself working more and more with Ojars Sovers on modeling and analysis issues. That led to our collaboration on the MODEST VLBI modeling books that some of you have seen.

I've also been fortunate to have learned from being a guest scientist. Noriyuki Kawaguchi and the Kashima group invited me for a three week stay in 1988. Martine Feissel and Anne-Marie Gontier hosted me at the Paris Observatory in 1996. More recently, Patrick Charlot's group in Bordeaux were gracious hosts to me in the summer of 2005.

If I were to cite one experience that challenged me to become a VLBI expert, it would be serving on the ICRF team under Chopo Ma. My task was to compare JPL's MODEST software with GSFC's CALC/SOLVE and the Paris Observatory's Gloria. Resolving model differences to the picosecond level really forced me to learn VLBI in detail.

NASA is distributed over several locations. What is the difference between JPL and GSFC?

NASA has centers all over the U.S. We are all one NASA, but, yes, there are some differences. GSFC is a regular NASA center, whereas JPL is a government/university hybrid—technically known as a Federally Funded Research and Development Center (FFRDC).

What is your daily duty at JPL?

I lead a task to develop reference frames for spacecraft navigation. This involves VLBI measurements of Deep Space Network antenna locations and measurements of quasar angular coordinates. I select sources, create experiment schedules, supervise setup of the passes at Goldstone, oversee correlation processing, fringe fitting, and run the astrometric analysis. I write utility software, manage budgets, and train new group members. I also act as the user representative for design reviews of everything from Digital Back Ends (DBE) to atomic clocks. So I'm a jack-of-all-trades.

How large is the analysis group at JPL contributing to the IVS? Who is doing what? What exactly is the contribution?

Our group is called the Deep Space Tracking Systems group and is under the supervision of Charles Naudet. We have about ten people at any given time. Jim Border and Peter Kroger specialize in spacecraft VLBI measurements. My reference frame team of Durga Bagri, Gabor Lanyi, and Andres Romero-Wolf provide the TRF and CRF used for the spacecraft measurements. Steve Lowe has written our observation scheduler, software correlator, and fringe fitting codes. We have two semi-retired consultants: Alan Steppe and Ojars Sovers. At the moment, we have a summer intern, Christina King from the University of Hawaii.

There are also non-VLBI projects within our group ranging from a pathfinder for neutrino-based astronomy (Charles Naudet, Kurt Liewer, Andres Romero-Wolf) to pulsars (Walid Majid, Chuck Naudet) to optical interferometry (Oliver Lay, Kurt Liewer). I should also mention that within our section of about 100 people, we have several groups that provide expertise which is very valuable to VLBI work: Robert Navarro's Digital Back End group, Richard Gross's multi-technique earth orientation group, Robert Tjoelker's atomic clock group as well as several GPS groups.

Why is your work seen as important?

JPL needs high-quality reference frames for spacecraft navigation.

Is it difficult to justify your activities in a competitive environment?

The technical justification for high accuracy reference frames is very solid. Of course, funds are tight here as they are at most places, so constant vigilance is necessary.

How important is VLBI for NASA/JPL (+GSFC) in the future?

The VLBI technique is critical and unique for spacecraft navigation and for the UT1-UTC component of earth orientation. VLBI is one of several techniques contributing to the TRF, but the inertial stability of our sources is the special advantage of VLBI.

What do you think in this regard about the VLBI2010 project of the IVS?

JPL played an early role in the design of the 12-m dishes that are now being used for VLBI2010. We were pioneers in moving reference frame VLBI above 8 GHz. However, our spacecraft work requires us to access Ka-band. So for now, our use of the 2–14 GHz feeds will be restricted to special research projects. JPL has championed the use of Kolmogorov turbulence models (Treuhaft & Lanyi, 1987) in VLBI data analysis which has benefited VLBI2010 simulations and could well benefit operational analysis. I think we will all benefit from the faster, more uniform IVS network of VLBI2010.

Which research subjects related to VLBI do you consider to be important a) for the IVS and b) for your personal interest? Why?

a) Next generation hardware (Mark-5C, DBBC) will

improve sensitivity allowing new groups to join affordably in VLBI data acquisition and allow everyone to detect new objects. I'm very excited about the opportunities opened up by multi-Gbps recording.

b) My own research interests are in high frequency celestial frames: K, Q, and X/Ka-band. Why? I think that S/X is asymptotically approaching a limit due to source structure. I believe that the best way around this is to go to higher frequencies.

At the end of the day, what are your favorite activities, other than VLBI?

I have a number of interests outside of VLBI. For physical activity I enjoy bicycling. I commute to JPL everyday by bike—in fact I've never owned a car. For emotional expression I enjoy music. I play string bass and electric bass and also record music. For spiritual development, I earned a master's degree in theology and lead a weekly Bible discussion group. And of course, I love to travel to IVS functions to visit my colleagues. Thanks for this chance to share.

JPL VLBI research is done under contract with NASA. Government sponsorship acknowledged. Copyright 2011 California Institute of Technology.



Aerial view of the JPL campus in the foothills of the San Gabriel Mountains.

Did you know?

Our JPL VLBI group loves to collaborate:

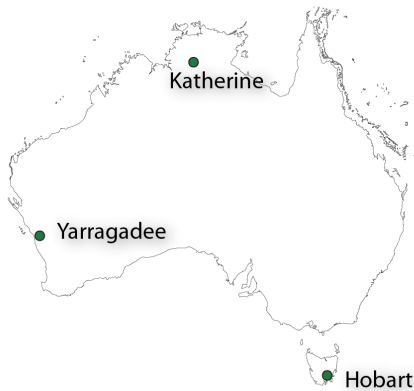
- A JPL-led collaboration produced the first VLBI fringes to an orbiting antenna (Levy et al., Science, 1986). Congratulations Radioastron for returning VLBI to space!
- JPL developed 1-mm level line-of-sight WVRs for the Cassini mission gravity wave search (Bar Sever et al, 2007).
- JPL-led collaborations are extending the ICRF to higher radio frequencies (Lanyi et al., 2010; Jacobs et al., EVGA, 2007 & 2010).
- Tired of photons? JPL is collaborating on a pathfinder for neutrino-based astronomy (Gorham et al., Project ANITA, 2009).

Full AuScope VLBI Network Commences Operations

— Jim Lovell, University of Tasmania

All three telescopes in the new AuScope VLBI array are now regularly participating in IVS observations.

The AuScope project began in 2006 when the Australian Government, through the National Cooperative Research Infrastructure Strategy (NCRIS) initiated the program “Structure and Evolution of the Australian Continent”, which is managed by AuScope Ltd. A major component of this project is the establishment of a national geospatial framework—including satellite laser ranging; ultra-precise gravimetry; a network of ~100 GPS receivers; three new VLBI observatories to be operated by the University of Tasmania at Hobart, Tasmania (Hb), Yarragadee, Western Australia (Yg), and Katherine in the Northern Territory (Ke); and a correlation facility to be operated by Curtin University in Western Australia: The AuScope VLBI Array.



The AuScope VLBI array.

The telescopes at Katherine and Yarragadee significantly improve the geographic coverage of geodetic VLBI facilities in the southern hemisphere. The Katherine telescope is co-located with a new AuScope GNSS antenna, while the Yarragadee telescope adds VLBI to the pre-existing MOB-LAS-5 SLR, GNSS, and gravity facilities maintained by Geoscience Australia.

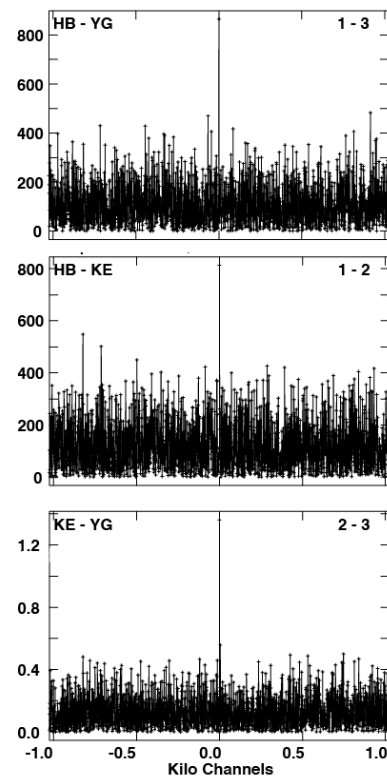
Construction of the first AuScope telescope at Hobart was completed in 2009 and officially opened at the IVS General Meeting on 9 February 2010. Following a period

of commissioning, testing, and debugging, the Hobart telescope made its first successful IVS observation in October 2010. Construction and commissioning at the other two sites continued in parallel. Yarragadee made its first successful IVS observation in May 2011 and, following a successful full-network fringe check on 8 June 2011, all three antennas participated in an IVS observation for the first time: R4487 on 16 June 2011.



The AuScope VLBI 12-m antenna at Yarragadee (Jim Lovell).

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First fringes between all three telescopes from observations made on 8 June 2011, processed at the Curtin University software correlator.

Each VLBI observatory is equipped with a 12.1-m diameter antenna, designed and constructed by COBHAM Satcom, Patriot Products division. The characteristics are: 0.3 mm of surface precision (RMS), fast slewing rates ($5^\circ/\text{s}$ in azimuth and $1.25^\circ/\text{s}$ in elevation), and acceleration ($1.3^\circ/\text{s}^2$ in both axes). All three sites are equipped with dual polarization S and X-band feeds from COBHAM with room temperature receivers, developed at the University of Tasmania by Prof. Peter McCulloch. The receiver systems cover 2.2 to 2.4 GHz at S-band and 8.1 to 9.1 GHz at X-band. System Equivalent Flux Densities (SEFDs) are 3500 Jy in both bands. Data digitization and formatting is managed by the Digital Base Band Converter (DBBC) system from HAT-Lab, and data are recorded using the Conduant Mark 5B+ system. Each

NEWS...

site is equipped with VCH-1005A Hydrogen maser time and frequency standards from Vremya-CH.

At Curtin University of Technology the software correlator, running DiFX, is installed on a 20-node Beowulf cluster. Three Mark 5B+ VLBI playback units are integrated into the cluster, for compatibility with the AuScope VLBI recording systems.



Sunrise at Nitmiluk (Katherine Gorge), Northern Territory (Jim Lovell).

All three observatories were designed and constructed to be remotely controlled and monitored to keep operating costs at a minimum. Operation of the AuScope VLBI array is being carried out from a dedicated operations room on the Sandy Bay campus of the University of Tasmania.

Upcoming Meetings...

Journées 2011 Vienna, Austria September 19-21, 2011	AGU Fall Meeting San Francisco, CA December 5-9, 2011
Decoupling Civil Timekeeping from Earth Rotation Exton, PA October 5-6, 2011	Workshop on VLBI2010 Specifications Wettzell, Germany March 1-2, 2012
10th Int'l e-VLBI Workshop Broederstroom, South Africa November 13-16, 2011	7th IVS General Meeting Madrid, Spain March 4-9, 2012

<http://ivscc.gsfc.nasa.gov/meetings>

Workshop on VLBI2010 Specifications in March 2012

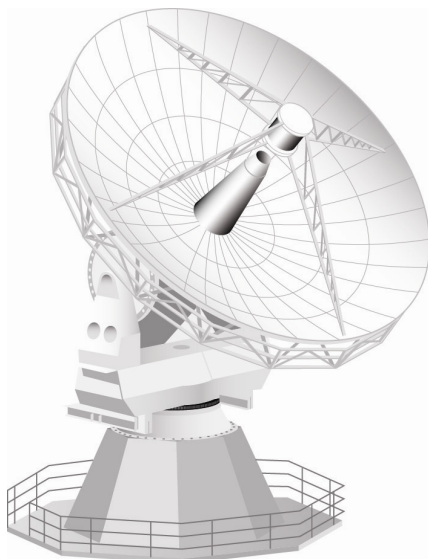
– Bill Petrachenko, NRCAN; Dirk Behrend, NVI, Inc./GSFC

The VLBI2010 Project Executive Group (V2PEG) and the VLBI2010 Committee (V2C) will organize a second VLBI2010 Workshop on March 1–2, 2012. The workshop will be held in Wettzell, Germany in the week directly preceding the General Meeting in Madrid, Spain, allowing overseas travelers to the GM to combine the two meetings into one big trip.

The purpose of the workshop is to provide information to stations and the agencies that support them to requisition systems fully meeting the requirements of VLBI2010. Detailed specifications will be provided along with suggested manufacturers and expected costs where they are known. The two-day workshop will be divided roughly into one day for the VLBI2010 antenna and one day for the rest of the system, including front end (feed/LNA/cryogenics), calibration (PCAL and noise cal), signal and clock distribution, flexible down-converters, digital back ends, recorders, eVLBI, and monitor and control. The program committee consists of Bill Petrachenko (chair), Brian Corey, Hayo Hase, Alexander Ipatov, Alexander Neidhardt, and

Alan Whitney. Manufacturers will be encouraged to attend (perhaps with information booths) to make first contact possible.

The first announcement for the meeting is planned to be sent out in August. The workshop is expected to be extremely useful for anyone contemplating direct involvement in VLBI2010.



The May 2011 TOW at MIT Haystack Observatory

— Stuart Weston, IRASR, AUT University, New Zealand

We had been waiting impatiently for nearly one year but finally Tim Natusch and I from our station 'Ww' travelled just about half-way around the world to attend this esteemed gathering held at that VLBI place of pilgrimage—Haystack. I did complete the circumnavigation, but that's another story. We arrived on the Saturday evening having left Saturday morning from New Zealand and spent nearly 22 hours in planes and LAX, very tired to find the New England weather was colder than the antipodean winter we had just left. I was very surprised, as it is the same latitude as southern Europe and it was May. Seems summer is slow to arrive here, apparent from the many bare trees, some only just starting to open their new shoots.



Author Stuart Weston (foreground) deep into an operations session at the Westford Antenna.

For those of the attendees who had arrived by the Sunday morning, a tramp was organized up Mount Watatic, which was a great way to blow the cob-webs away and also fulfilled the role as an unofficial or pre-icebreaker. Sunday evening at the main accommodation was the official icebreaker, an opportunity to meet attendees who we had gotten to know through emails and the e-VLBI conference in Perth last year. This reinforced for me the feeling that the IVS community is like an extended family. For us, as a new station, establishing new friendships and relationships and an opportunity to meet old friends and colleagues from within the VLBI community was beyond measure.

We had 64 attendees from 15 countries, the largest contingent being from the USA; some were old hands, but some of us were new boys such as myself from a mixture of new and existing IVS stations. Some attendees had an equally arduous journey as ourselves having come from Japan, Korea, and Ny Ålesund from above the Arctic Circle. Well done and thank you for making the effort to attend; it's great to have such a mixture of nationalities.

Prior to coming, Tim and I had tried to go through the session summary to spread ourselves amongst as many as possible. Not easy. I thus focused on the more operational sessions, but there were so many others I would have loved to attend.

The sessions were a mixture of old classics like "Experiment Pre-Checks and Operations" by the dynamic duo Rich Strand and Mike Poirier. Then there were the new sessions with respect to the RDBE presented by Chet Ruszczyk and DBBC by Gino Tuccari. I attended the "Understanding Correlator Feedback". Was I the only station operator to attend this? I felt it was important to attend and understand, as this form of feedback could help us to improve our operations and data quality.

It became apparent that changes are coming to that old-station-operatives-favorite, the Field System, with new software such as e-RemoteControl presented by Alexander Neidhardt and Martin Ettl.

The feedback sessions I think highlighted two main issues. From the correlator perspective, station operators need to be more verbose in their comments added to the Field System log, so that time isn't wasted processing scans which are poor or invalid. The stations reported the difficulty in searching the available documentation on-line, which is a wealth of information but hard to mine. I would ask that the centers listen to what the troops at the front line (the station operators) are giving in feedback. Please don't dismiss, as it can come from a level of frustration with software, hardware, or documentation (or lack thereof, certainly for the new hardware), and we wish to improve our operations and hence data quality. But also highlighted was that Mark IV spare parts are becoming very thin on the ground. So, will more stations be moving faster to a digital solution?

The catering and general administration during the week was superb, so a big thank-you to the organizing committee and especially to Heidi and Dirk.

The last-but-one session was an introduction to the Mark 6 via a very impressive 16 Gbps demonstration presented by Alan Whitney in collaboration with XCube. An observation from a station-operation perspective is that we will have to handle more disk-packs and an associated increase in handling and shipping; at those data rates (burst mode of 32 Gbps) we will jump well ahead of the curve for high speed research networks and the ability to deliver data to the correlator via e-transfer for quicker correlation and processing for the analysts.

We are entering a period of rapid change with respect to hardware and associated software from a station perspective: Mark 5C, Mark 6, DBBC, RDBE, and e-RemoteControl. The challenges ahead are for stations to transition to this new en-

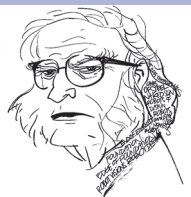
vironment and maintain or even improve the quality of the data collected. I ask the following questions. How can new stations be brought into the IVS community and produce high quality data within the shortest possible period? Should we expand our horizons for how we can adopt other technologies to aid new station-operation staff and new stations?

I just wish we had been able to attend a TOW a lot earlier than we did, but we had a fantastic time with lots of information to assimilate.



Alan Whitney with one of the Mark 6 disk packs.

Finally, a big thank-you to MIT Haystack Observatory for hosting the event; to the local organizing committee and during the week Heidi and Dirk; to the session presenters; and lastly to the attendees who made it all worthwhile. So, I look forward to seeing you all again in two years when, hopefully, Warkworth will be a fully productive digital station.



The saddest aspect of life right now is that science gathers knowledge faster than society gathers wisdom.
- Isaac Asimov



Participants at the 6th TOW.



Please remind me why we came to the TOW again. [Editor's note: Beer consumption can impair your vision but eating green salads may lessen the effect.]

The IVS Newsletter is published three times annually, in April, August, and December. Contributed articles, pictures, cartoons, and feedback are welcome at any time.

Please send contributions to ivs-news@ivscc.gsfc.nasa.gov.

The editors reserve the right to edit contributions. The deadline for contributions is one month before the publication date.

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NEWS...



Recent Changes in Position in the IUGG/IAG/GGOS Realm

– Dirk Behrend, NVI, Inc./GSFC

Before and during the XXVth General Assembly of the International Union of Geodesy and Geophysics (IUGG) in Melbourne, Australia several executive positions of the IUGG, the International Association of Geodesy (IAG), and the Global Geodetic Observing System (GGOS) were filled. It is probably fair to say that the selections are in general in favor of geodesy and in particular in favor of VLBI.

The outgoing IAG President, Michael Sideris (Canada), was elected the new Vice President of the IUGG, meaning that at the 2015 IUGG General Assembly he will likely become IUGG President. IAG is one of eight associations that make up the IUGG.

The new IAG President is Chris Rizos (Australia); the new IAG Vice President is Harald Schuh (Austria).

Also GGOS had a change in leadership. The new GGOS Chair is Hansjörg Kutterer (Germany), taking the reins from Markus Rothacher (Switzerland). The GGOS InterAgency Committee (GIAC) is now headed by John LaBrecque (USA, Chair) and Gary Johnston (Australia, Vice-chair) taking over from Dietmar Grünreich (Germany). The GIAC Secretariat is located at BKG in Frankfurt, Germany.



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