NERC Space Geodesy Facility **Appendix to Annual Report 2007-08**

Report on operations for the period 2007 May to 2008 April

Annual summary

Our main development work this year has fallen into 2 areas.

- kHz
  - Build the hardware safety controls for laser
  - Software to control laser safety and laser firing
  - Upgrade software for reduction of kHz data
  - Investigate all optical components to maximize outgoing/returning energy
  - Investigate new detector (MCP/PMT) to minimize losses due to daylight

- Geostationary tracking facility (GEOF) for MoD
  - Develop software/hardware to control 16inch Meade telescope
  - Collect images using newly purchased CCD camera
  - Develop software to read/analyses CCD frames to detect stars/satellites

At the same time we have continued

- Full coverage of SLR tracking for all ILRS objects
- Analysis of GPS data produced by HERT and HERS
- Analysis of SLR data as an ILRS analysis centre
- Glonass observations and other requested observations for MoD
- Continued monitoring of GNSS status for MoD
- LIDAR
- Collect regular Gravimeter data
- Taken the Gravimeter to a European inter-comparison of Gravimeters

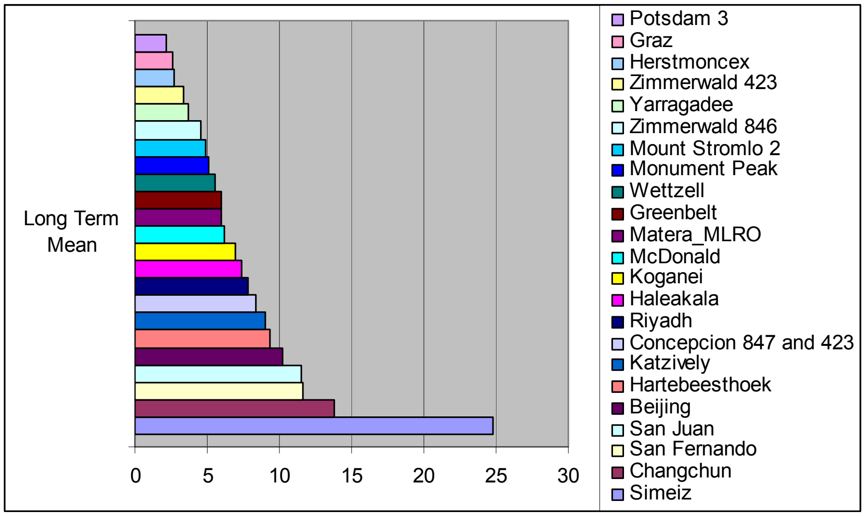
1 SLR

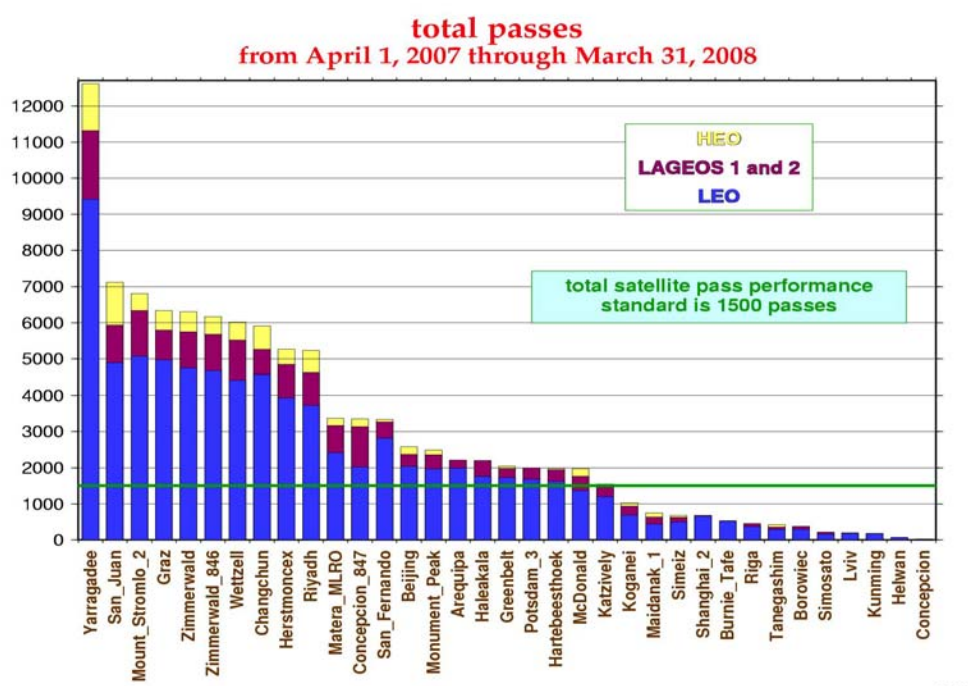
1.1 Annual totals and statistics

Pass totals for the year 2007 April to 2008 March

Altimetry							
ERS-2	335	Envisat	348	GFO-1	306	Jason-1	533
Geodetic/Gravity							
Lageos-1	551	Lageos-2	359	Etalon-1	64	Etalon-2	81
Champ	141	Grace A	140	Grace B	151	Beacon-C	217
Starlette	379	Stella	197	Ajisai	450	Larets	289
Navigation							
GPS35	53	GPS36	29	Glonass	857	GIOVE	45
Other support							
Anderra	58	Anderrp	72	Icesat	206	Terrasar X	119

The quality (precision) of the laser data is estimated from the results of three ILRS analysis centre weekly LAGEOS orbital solutions; orbital fits are performed during which station coordinates are held fixed at their ITRF2005 values, but pass-by-pass range and time bias values are solved-for. Over the previous three-month period the standard deviation about the mean of these pass-by-pass range biases is considered a measure of short-term system stability. Similarly, using results from the previous year, long-term stability is estimated from the standard deviation of the monthly range bias estimates. These metrics do not address range accuracy of course, but are valuable as a method of comparing each station's system stability. The two diagrams below show these long-term and short-term RMS range stability estimates, derived from the results of the analysis centres DGFI, Hitotsubashi University, JCET, MCC and SHAO. The third plot gives the number of observations made by each station to high-orbiting (GNSS, Etalon), medium-orbiting (LAGEOS) and low-orbiting (gravity, altimeter, etc.) satellites.

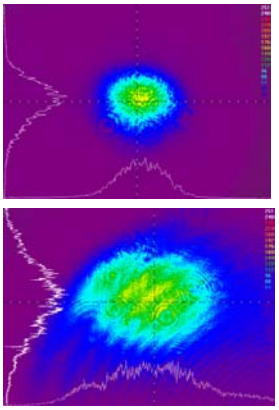




1.2 New launches

There are six new Glonass satellites numbered 104-109. Also launched is the second European Galileo satellite, GIOVE-B and altimetry satellite TerraSAR-X. TerraSAR-X is an X-band SAR mission for scientific research and applications. It is the first satellite to be built in a public/private partnership in Germany. It carries the experimental Tracking, Occultation and Ranging (TOR) package provided by GFZ and CSR. TOR consists of a two-frequency CHAMP-type GPS receiver and a CHAMP Laser Retro-Reflector.

1.3 kHz Ranging



Ranging whilst using the KHz laser this year revealed serious doubts regarding the energy output of the laser. The purchase of an energy meter and a beam profiler quickly showed that things were indeed very wrong. The beam profiles taken inside the laser (top) and in the 'tunnel' (bottom) taken ~1m away from the exit of the laser are shown here, the second clearly exhibiting a diffraction pattern.

The energy meter revealed a maximum energy output half that of specification (0.42mJ per pulse) and re-alignment of the laser optics did not improve the output. After discussion with the laser distributor (Photonic Solutions) it was concluded that this energy loss may have been due to a faulty diode module therefore a new diode module was ordered and a service visit arranged (Dec 2007). Although the diode module was changed during the service visit no improvement was seen in the energy output. It was therefore concluded that the diode controller was at fault. With the original diode module back in place the drive volts were increased to maximum by Photonic Solutions which then resulted in full energy output. This is not a user adjustment and discussions are ongoing with Photonic Solutions regarding this issue.

Due to the relative increase in backscatter from components, an accident occurred in February 2008 in which a specular reflection caused temporary ocular damage to a member of staff whilst aligning the laser. Since this time large changes in operational practice for aligning the laser have been implemented and new first-class laser goggles purchased. This evidence combined with optical experiments and ranging return statistics indicates that the laser had not been at full specification for some time, perhaps since installation. However the latter conclusion cannot be substantiated to the manufacturers' satisfaction.

With the laser energy now at full-spec, it is sometimes burning out an exit window from the frequency -doubler crystal. The problem is thought to be due to beam-focusing generated within the crystal. The energy output is now regularly tested and quickly detects when problems begin to arise with this optic. Investigations are continuing.

Also notable in early 2008 was a power-cut incident which wiped the EPROM memory of the laser controller, the cause of which is still unexplained. It was necessary to send the laser controller to Photonic Solutions for reprogramming.

R&D

Use of the energy monitor allows qualitative investigation of the optics throughout the outgoing laser path. So far this has enabled a polarization investigation as a function of telescope azimuth and a mirror-1 (M1) reflectivity assessment. Qualitatively, there is an impression during ranging of a large variability in satellite returns in two quadrants of the sky. To address this, the energy monitor has been placed after mirror 3 thereby allowing measurements to be taken with only one varying component, M2 – the mirror that rotates with telescope azimuth. These tests show an 8% variation in power output from the 360° rotation, and we now require the next step of a full 360° rotation combined with effects from elevation variation.

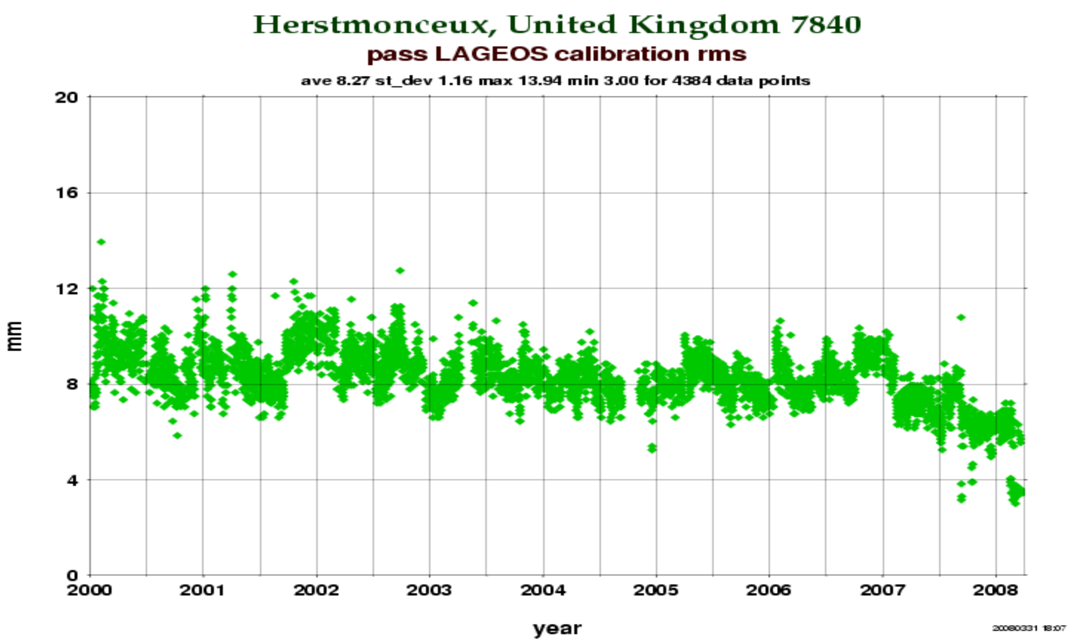
After this test was complete it was decided to assess the energy loss from each optic up to and including mirror 1. Although the effects are very close to the sensitivity limit of the monitor, it was found that each mirror between the laser and the first coude mirror incurred losses of between 0.5-2%. The loss associated with mirror 1 was found to be substantial and after the replacement of mirror 1 the remaining loss was traced to the window prior to M1. This was removed (this window forms an air seal for the clean dry air flowing through the coude system of mirrors). The removal of the window was only possible after the installation of the soft wall clean room around the laser and 'tunnel' optics.

	Loss due to M1	Loss due to New M1	Loss due M1 with window removed
Nd:YAG (13Hz)	26%	13%	2.6%
Nd:VAN (2kHz)	17%	11%	2.7%

1.4 System precision improvements due to ET/kHz

Shown here is the calibration RMS since 2000. We started using the accurate Event Timer in February 2007, after which an improvement in precision can be seen.

KHz and 10Hz data were both regularly collected after February 2008; the two precision-regimes can clearly be seen.



1.5 Analysis

Analysis of the global laser data from the two LAGEOS and two ETALON geodetic satellites has concentrated on a re-analysis of the data from 1983 to date. The orbital models are being updated with new ocean-tide and loading models and a series of range bias values determined within the Analysis Working Group are being implemented. The resulting un-constrained time-series of site coordinates and EOPs will be combined with those from other ACs as input to the next realization of the ITRF. In parallel with this work, we now generate 7-day-arc solutions for daily EOPs (x and y pole and length-of-day) each day in support of an IERS request for ILRS results towards its Rapid Service.

1.6 Global network

South Korea has plans for two new SLR stations, one mobile and one fixed. The completion date for both of these systems is 2010.

China is looking to upgrade some of its stations to kHz systems. Delegations from both Korea and China visited Herstmonceux as part of their preliminary investigations.

The US Next Generation System (formerly SLR2000) is receiving greater NASA support, including more dedicated staff effort. Those involved are hopeful that the prototype will be operational during 2008, having already obtained returns from LEO to MEO.

1.7 Photometric observations.

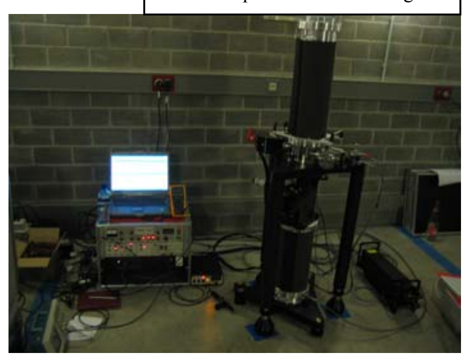
The laser ranging system has continued to be used for tracking requested objects for the MoD to monitor reflected sunlight variations. These results have been communicated to the MoD as short reports.

2. GRAVIMETER FG5-229

The gravimeter has continued with its time series of weekly data as usual until mid-May 2008 when it was shipped back to the US for its bi-annual (and first) service by Micro-g Lacoste. The most notable event this year was the attendance at a European inter-comparison of gravimeters held in Walferdange, Luxembourg.

<u>Walferdange Report</u>

229 on pier C3 - Walferdange



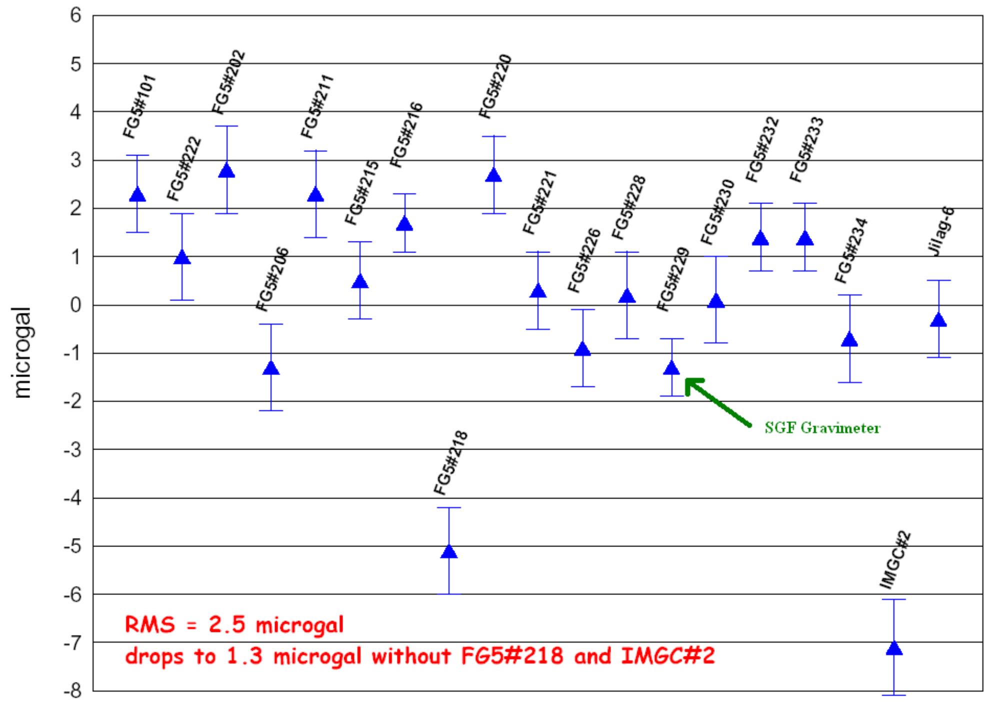
Visit Date 2007 November 1 – 11

Location ECGS mine, Walferdange, Luxembourg

Purpose of Visit Inter-comparison of Absolute Gravimeters

To verify the accuracy of any FG-5 regular inter-comparisons are held. In Europe the primary inter-comparisons are held at BIPM Paris and in Walferdange, Luxembourg. From the inter-comparison of 3 or more machines, usually taking twelve hours of data on different days on different 'piers', the relative accuracy of the machine can be determined.

The inter-comparison results are shown below. Although it appears as if 229 is reading very slightly low it is thought that this might be attributed to the fact that low gravity readings were obtained on two piers where the super-spring did not settle into a stable state. Note – One Gravimeter from the Proudman Oceanographic Laboratory also participated in the inter-comparison (FG-5 222).



3. LIDAR

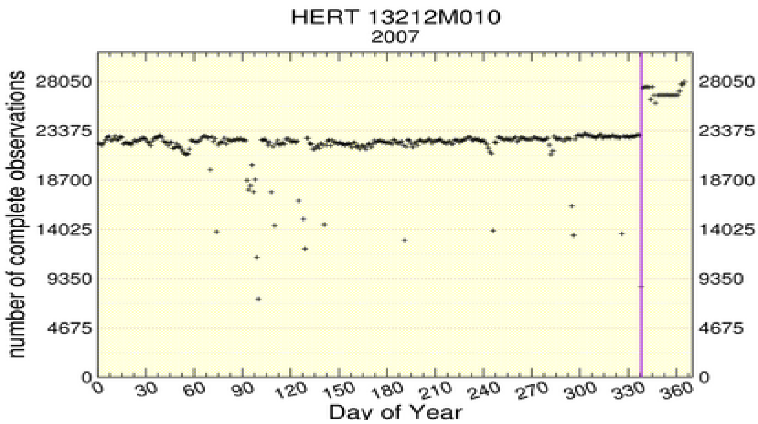
Development of the LIDAR system is ongoing. Following the preliminary tests that were carried out last year we have developed a system using a Hamamatsu Photomultiplier Tube, PMT amplifier and a National Instruments high-speed 14-Bit digitizer. During experimental runs the digitizer has been gated in time with the laser firing and the data, collected from the PMT, is then sampled many times during each shot. Over the experimental period of typically a few minutes, the shots are averaged together and produce a vertical profile of atmospheric response, which is mapped, and various layers detected. These tests have shown that the port first chosen on the telescope to house the PMT, where laser backscattered light has been greatly reduced via a dichroic mirror, has proven to be unsuitable.

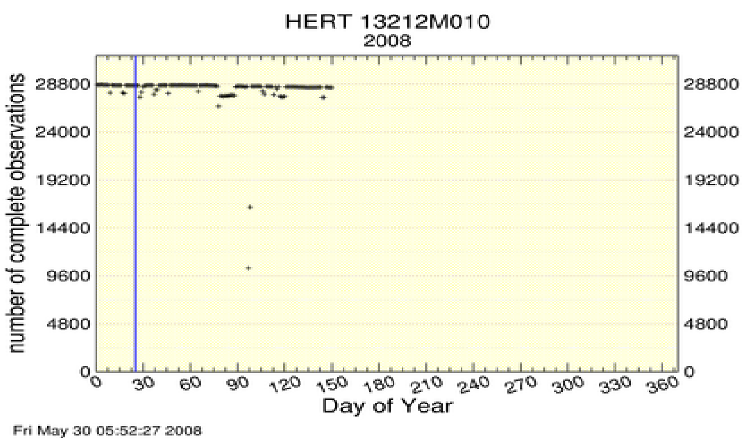
Therefore development of the detector-box will be undertaken to place the PMT in a more suitable position, allowing the light that 'hits' the PMT to be controlled, filtered and better focused onto the window of the device. In its new position, the overlap function, i.e. when the laser beam fully enters the telescope's field of view, can be relied upon to be consistent and better controlled. Future enhancements include an additional dedicated detector system to allow LIDAR and SLR to be carried out simultaneously. Some analyses of these preliminary results have shown that the use of the 2.0 kHz Laser will be unsuitable for this work, the 10 Hz Laser having far more energy to provide sufficient backscatter light for the PMT.

4. GPS and GLONASS Continuously Operating Receivers

Both IGS/EUREF sites (HERS and HERT) have continued to submit data over this period. The main development this year has been the replacement of the Ashtech Z-18 at the water tower HERT monument by a new Leica GPS/Glonass receiver. The new receiver is operating very well following a smooth changeover and both reliability and data quantity (actual satellites tracked) has improved. We have moved the Z-18 to the OS solar pillar monument located between HERS and HERT. This monument had been used to test the Leica before switching over and so we had a month of data to compare. This has a dual purpose; initially it was to confirm that recent coordinate instability in the analysis of Z-18 data at HERT was due to the tracking problems that receiver was having and not a problem with the monument itself. We can now confirm that the poor data followed the Z-18 to the solar pillar and the new receiver at HERT is performing well. In addition a medium/long term occupation of a third location on site will help with the very short baseline analysis being carried out, hopefully resolving some of the long term trends we have seen in the HERS – HERT baseline. If the first 6 months of this experiment shows promising results, it may be sensible to buy a further new receiver to occupy either the HERS IGS site or the solar pillar; this would enable us to dispense with the Z-18 altogether.

Below are the plots from EUREF showing the total observations made by HERT for 2007 and 2008, the change over to the Leica receiver is marked by a purple line. The large increase in quantity is due to the new receiver tracking more Glonass satellites (those with zero or negative PRNS as well as unhealthy satellites) as well as no longer suffering the communication errors that would periodically affect the Z-18.





5. GEOF

A new system, the Geostationary Facility, has been developed to carry out work for the MoD. This uses the 16-inch Meade telescope which was previously used for the MoD PIMS project. Control of the telescope is via the old laser ranging PC and a newly purchased "Starlight Express" CCD camera carries out imaging.

The main thrust of the work has been in developing software to automatically read the thousands of CCD images taken during a typical observing run, carry out analyses and produce brightness variation plots for requested satellites. Most of the control and analytical software is complete. Data has been collected on a regular basis since late February.

6. ILRS workshop in Grasse

a. Papers presented.

Graham Appleby co-chaired a workshop session called “Counters performance, calibrations, and upcoming event timers”. This session included much discussion of the recent work by Philip Gibbs on Stanford counter calibrations. Matthew Wilkinson presented his work on automatic track detection and also co-chaired the “kHz SLR” session. The SGF is the second SLR station to operate at kHz repetition rates and in this session Matthew presented a full account of the Herstmonceux experiences.

b. Highlights.

Many SLR stations presented plans to operate at high repetition rates in the future. This included plans by a number of stations to upgrade to 100Hz, which was considered advantageous because of the relatively high laser pulse energy. Stations are also preparing for challenging future projects including time transfer to the Jason-2 satellite and one way range transponder measurements to the Lunar Reconnaissance Orbiter. Both missions are to be launched this year (See R&D in the meeting papers)

7. Infrastructure.

The proposed upgrade to the computer LAN has been completed. The housing of the website is in place on a LINUX server and is going through final software upgrades. The site will be set live once all the automated processes, including daily QC of laser and GNSS data, are migrated from the Monks Wood machines. Its address is http://sgf.rgo.ac.uk

The meeting room has been completed. This involved gutting the room and starting again from scratch, with the installation of the membrane being done correctly. After the installation, it has been completely redecorated and carpeted and has had the door to the cellar widened to allow better access for equipment into the gravity corridor.

To assist in keeping the gravimeter clean a second wall has been added in the corridor to form an airlock before entering the gravimeter room.

The kHz laser has also had an environment upgrade and is now housed in a soft-wall cleanroom.

8. SGF Staff

Toby Shoobridge joined the staff in June 2007 as a trainee mechanical engineer working with David Benham; Toby’s line manager is Rob Sherwood. David has continued to be employed on 6 month casual contracts, two days per week.

9. Public relations.

We have had visits from Newcastle University Geomatic department, the Open University Physics society, the Hydrographic Office as well as a number of local societies.
We also gave tours of the facility during the Astronomy weekend organised by the Science Centre. During the weekend we showed about 100 people around.
A couple of lectures on space geodesy and the work of the SGF were given to ISC students taking the undergraduate astronomy option. A remote lecture was given on the work of SGF, including a live satellite ranging session, to students at Hitotsubashi University, Tokyo, via Skype during a lecture by collaborator Dr Toshi Otsubo.
We are involved in the work experience project. During 2007 we gave six 15 year old students and one A-level student one week’s work experience.