SERVICES & FACILITIES ANNUAL REPORT - FY April 2004 to March 2005

SERVICE Space Geodesy Facility SGF	FUNDING Direct from 1999	AGREEMENT	ESTABLISHED as S&F 1994, operational from 1983	TERM 5 years

TYPE OF SERVICE PROVIDED: SGF is an operational, state of the art observational Facility that makes very accurate measurements of the distances of a constellation of Earth orbiting artificial satellites in support of national and international research into dynamic Earth processes through enabling precise orbit determination and realisation of a consistent global reference frame. The observations are made available rapidly and freely to the worldwide community through the data centres of two of the Services of the International Association of Geodesy, namely the International Laser Ranging Service (ILRS) and the International Global Navigational Satellite System Service (IGS), with which Services the Facility is registered. The Facility also carries out an R&D programme, in order both to keep its observational capabilities at an international level of competitiveness and also to keep abreast of and contribute to space geodetic research. In this regard, particular emphasis is placed upon improving the value and accuracy of laser range (SLR) observations, contributing to an international programme to improve the realisation of the Terrestrial reference frame which underpins many areas of global geodetic research and seeking new opportunities to increase for the community the geodetic value of the site.

The nature of the work and the need, as a member of an international observational network, to make the observations available as quickly as possible to the community means that as a rule users do not apply directly to SGF for services. However, as part of the global tracking effort, the work of the Facility provides the raw material to underpin several areas of NERC science. Observations of the geodetic satellites by the SLR system, which is collocated with two continuously operating GPS receivers, contribute to the definition of a global geocentric reference frame: Herstmonceux is one of *ten key worldwide reference stations* that define the scale and origin of this frame. Observations of remote-sensing satellites allow accurate computation of their orbits within this same, well-defined reference frame. In turn, satellite altimetry and SAR measurements to the oceans, ice caps and land areas can be reduced accurately using this precise knowledge of the positions of the satellites. Such data and products impact upon ongoing UK studies into for example long-term variation in sea level (e.g., Newcastle), ocean circulation/anomaly dynamics (NOC, POL), polar ice mass-balance and response to climate change (e.g. CPOM, UCL and Bristol), improvement of global digital elevation models and large-scale river-level monitoring (De Montfort), forest vegetation dynamics (CEH).

ANNUAL TARGETS AND PROGRESS TOWARDS THEM

1. Maintain and improve upon laser ranging accuracy and quantity of data obtained: Measured by the ILRS, the Facility was seventh in the world in 2004 in quantity of data and second in terms of quality, with long-term Normal point stability (accuracy) of about 5mm. Quantity of data has slightly suffered this year (ranked fifth last year) because of telescope system downtime (see below and in Annex).
2. Maintain the quality of the GNSS observations made from the two IGS receivers on site, and convince the community that HERS data quality is now fully restored following an extended period of inferior data several years ago. Much better on-site QC processes in place; several opportunities taken to 'talk up' and present the HERS data results.
3. Upgrade the ageing and failing telescope drive electronics. A major upgrade, with significant periods when tracking could not be carried out. Much software and hardware work done by team, in support of contractors. Work successfully completed, to great credit of SGF personnel involved, and telescope tracking integrity now much improved.
4. Respond to NERC Capital Bid initiative. Case made for laser upgrade (to increase precision from 8 to ~3 mm single-shot RMS and greatly reduce target acquisition time, hopefully to a few seconds) and to purchase absolute gravimeter (with POL, to increase user-base and capability of Facility). Proposal was initially rejected, but later funded through S&F. Both purchases in train. Expect to be operational with these expanded science capabilities by end of 2005.

SCORES AT LAST REVIEW (each out of 5)		Date of Last Review: 2003		
Need	Uniqueness	Quality of Service	Quality of Science & Training	Average
5	5	5	5	5

CAPACITY of HOST ENTITY FUNDED by S&F	Staff & Status	Next Review (January)	Contract Ends (31 March)
100 %	1 at Band 5, 4 at Band 6, 2 at Band 7, full-time.	2008	2009

FINANCIAL DETAILS: CURRENT FY						
Recurrent Allocation £k	Unit Cost £k			Capital Expend £k	Income £k	Full cash cost £k
	Unit 1	Unit 2	Unit 3			
340				65	220	410

FINANCIAL COMMITMENT (by year until end of current agreement)				
2004-05 120+300	2005-06 120	2006-07 120	2007-08 120	2008-09 120

STEERING COMMITTEE	Independent Members	Meetings per annum	Other S&F Overseen
NSGSC	7	1	BIGF

APPLICATIONS: DISTRIBUTION OF GRADES (Current FY — 2004/05)

	α5	α4	α3	α2	α1	β	R*/Pilot	Reject

Users do not normally apply *directly* to the Facility for any products or services. The raw data from SGF, namely accurate observations of satellite positions, are made freely available in close to real-time as part of a commitment to two of the Services of the International Association of Geodesy (ILRS and IGS). From these raw observations both UK and international users and agencies derive the principal end products, which include accurate orbits of remote-sensing satellites, a global reference frame and measurements of the Earth's orientation in space. These products then underpin the scientific exploitation of the remote sensing data, such as altimetry and SAR, as well as being of scientific interest in their own right.

The laser ranging satellite tracking priorities are set by the steering committee (NSGSC) with UK users in mind, but again with knowledge of ILRS priorities.

Value-added products, such as orbital analyses, are directly solicited from SGF, both in terms of collaborative research work and reports written for co-funding partners, primarily MoD. Several activities, such as daily quality checks and production of orbital predictions, are carried out for the ILRS. This work is detailed later in this Annual Report.

USER PROFILE (current FY) **Combined non-Directed and Directed*

Since, as discussed, users do not normally apply for services to be carried out by SGF, it is not possible to attribute the bulk of the operation to a well-defined list of users. In an attempt to give as much information as possible here, we list national and international groups and agencies that are known to be international leaders in the space geodesy field a who therefore will be users either directly or indirectly of SGF products. UK: University of Newcastle, Institute of Engineering Surveying and Space Geodesy (IESSG, University of Nottingham), Centre for the Observation and M of Earthquakes and Tectonics (COMET, Universities of Oxford, Cambridge and UCL), Centre for Polar Observation an Modelling (CPOM, UCL, Universities of Bristol and Cambridge), Dept. of Geomatic Engineering, University College London, National Oceanography Centre (NOC, University of Southampton), Proudman Oceanography Laboratory (POL, University of Liverpool), De Montfort University, Ministry of Defence, British National Space Centre; European: EUREF; International: ESA, NASA, ILRS, IGS, IERS.

A literature search has been carried out to determine numbers of reviewed papers published during 2004 in the major geophysical and geodetic journals by UK (co-) authors. Publications are strictly filtered by being traceable to those technologies supported by SGF, including precise orbits for altimetric, SAR and gravimetric satellites, continuously operating IGS GPS systems, geodetic satellite tracking, Earth orientation and geocentre determination. Journals searched include Journal of Geophysical Research, Geophysical Research Letters, Journal of Geodesy, Marine Geodesy, Geophysical Journal International and Science. A total of 24 publications for 2004 resulted from this search. Of those, 8 are primarily in oceanography, 7 in solid Earth, 5 in polar, 2 in atmospheric science and 2 in underpinning technology. In terms of NERC strategic priority categories, 9 of these publications discuss Climate Change and 8 concern Underpinning Science.

Distribution of Projects (by NERC strategic priority)

Earth's life support systems	Climate Change	Sustainable Economies	Underpinning Science	Specific Research

OVERVIEW & ACTIVITIES IN FINANCIAL YEAR (2004/05):

SLR: The Facility remains a major contributor to the global data sets of high-quality SLR observations. Tracking support for the current **altimetry missions** ENVISAT, JASON-1, ERS-2, TOPEX/POSEIDON and GEOSAT Follow-on continued at a high level of priority. For ERS-2, ENVISAT, T/P and JASON-1, SLR measurements supplement for ERS-2 some PRARE data and for the others GPS/DORIS tracking data, whilst for GFO-1, **satellite laser ranging** remains the only precise tracking method.

The **geodetic satellites** LAGEOS and ETALON (two of each) are observed with high accuracy and frequently enough to provide a major contribution to global reference frame studies, an essential underpinning for global geodetic work. The ILRS Analysis Working Group (membership includes representatives from Newcastle and, as deputy co-ordinator, the HoS SGF) continued regular, weekly, computation and combination of SINEX-based solutions for station coordinates and Earth-rotation parameters. The group also made a significant contribution to the forthcoming ITRF2004, by computing 10-year, weekly solutions and combination products

The two vehicles of the **GRACE** gravity mission continue to provide a challenge for SLR tracking and for the rapid dissemination of accurate predictions. SGF is playing a leading role in this effort, via rapid orbital updates made available to the ILRS network. Both continue to be reasonably well tracked by the global SLR network. The role of the SLR technique in this mission, as for the ongoing **CHAMP** mission, is primarily an independent, but none-the-less important, check on the orbital quality derived from the onboard GPS receivers. The range measurements will also be used to aid precise orbit determination. Laser ranging to the LEO geodetic satellites **STELLA** and **STARLETTE** continue to be of value for determination of temporal variability of low degree terms in models of the Earth's gravity field. SLR measurements have continued to the **GLONASS** satellites and to the two **GPS** satellites that are fitted with retro-reflectors.

Through collaboration and real-time status exchange with the **EUROLAS SLR** facilities, SGF continues to champion the concept of an "intelligent" observing strategy, whereby systems maximise support for the wide range of satellites that require precise tracking. Surprisingly, the instances within the EUROLAS cluster of given satellite passes being tracked by more than one system are quite low; as a result of local operational conditions, including weather, nearly 60% of tracked passes are unique to a single station in the cluster.

GPS/GLONASS: The **Ashtech Z-18 joint GPS/GLONASS** geodetic receiver (IGS **HERT**) continues to work extremely well in its location close to the principal SLR calibration target some 100m distant from the main buildings of the Facility. Via a fibre link to the facility, the **HERT** system is configured to contribute 30-second data to IGS, simultaneously archive 1-second sampled data and stream navigational data direct to the internet as part of the EUREF-IP real-time GNSS Pilot Project (http://www.epncb.oma.be/_organisation/projects/euref_IP/index.html). The **Z12, IGS HERS** system continues to supply reasonable-quality 30-second data both hourly and daily to IGS. Daily quality checks on the Z12 and Z18 data are automatically carried out by SGF. SGF's new capability, via the MIT software GAMIT, to analyse GPS data is being put to good use to monitor both the quality of the HERS and HERT data and potentially the stability of the site itself within the ITRF frame. Both differential and global daily solutions are computed for this effort. This work does show some occasional problems with HERS data, and probably next year consideration must be given to purchasing a new receiver, with perhaps a re-location of the Z12 within the site to aid the site stability monitoring effort.

COLLABORATIONS:

A Memorandum of Understanding that guarantees SGF's daily supply of HERS and HERT data to **BIGF** was ratified by the HoS of SGF and of BIGF.

The **photometric capability** of the SLR system continues to be used to determine the spin vector of LAGEOS-2, which is an important parameter in precise orbital determination in terms of modeling non-gravitational forces. This is a continuing collaboration with NICT (Japan) and DEOS (Delft). For the ongoing collaboration with UCL on precise shadow-passage monitoring, photometric data from high-orbiting satellites were found difficult to obtain but efforts will resume this Autumn.

Surrey Satellite Systems Ltd. A joint unsolicited proposal between SSTL, SGF and several other UK groups to provide in-orbit validation of GALILEO Test Bed satellites GSTB-V2/A and V2/B was prepared and submitted by SSTL to ESA for funding. SGF contribution would be to host a GALILEO receiver, make laser range measurements to the two satellites and carry out orbit validation using the laser data, as per SGF published work with GLONASS and GPS. The satellite(s), primarily for frequency filing, are due for launch in late 2005, early 2006. This proposal was not funded, but it is possible that a receiver will nonetheless be installed at Herstmonceux. The ILRS has responded positively to an ESA request for laser tracking support of these test bed vehicles. SGF will ask NSGSC for its support of this request.

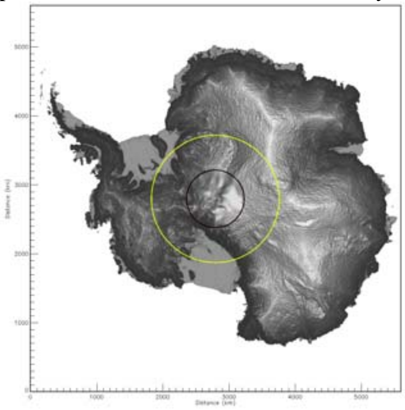
ILRS Analysis Working Group. Collaborating with research groups from five other international institutes towards the up-and-running 'official' weekly ILRS station coordinate and EOP product. SGF is currently submitting weekly solutions that are being combined with four other regular solutions. Involved in a joint response to IERS committing ILRS analysis combination groups to this activity, potentially involving Geomatics department, University of Newcastle-upon-Tyne.

ILRS Signal Processing Working Group. Leading the work towards the determination of precise values of centre of mass corrections for the geodetic satellites for the major tracking systems. Completed documentation of retro-array precise locations and characteristics. The information, in tabular form for all ILRS satellites, has been placed on ILRS website.

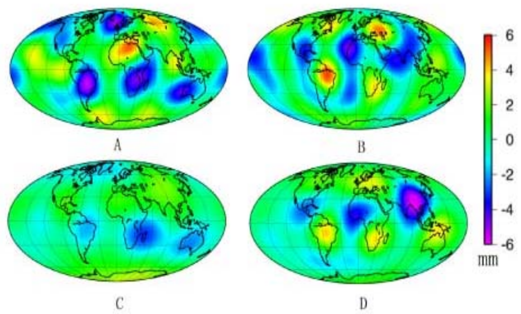
National Institute of Information and Communications Technology, Japan. Continuing the programme on analysis of SLR measurements to the ILRS-approved GLONASS and two GPS satellites that carry laser arrays. Paper and presentation at LR workshop in San Fernando, Spain.

ILRS Fall 2005 Workshop in Eastbourne, UK. SGF is hosting the bi-annual 'hands on' workshop in October 2005. Working Group and open sessions will be organized by ILRS working group coordinators and a strong contribution to the sessions is expected from SGF staff. It is likely that some 100 ILRS associates will attend the five-day event, which of course will include an evening visit to Herstmonceux.

SCIENCE SUPPORTED IN FY (2004/05):
Here we outline some of the work of the (mainly UK) community that depends either directly or indirectly on the observations or products from observations made by SGF, in its role as a leading member of International networks of such Facilities.



A new digital elevation model of the Antarctic from combined satellite radar and laser data. CPOM, University of Bristol, J.L. Bamber and J. Gomez-Dans. DEMS derived from radar altimetry near ice sheet margins and in other areas of steep relief tend to have both poor coverage and accuracy. To remedy this and to extend the coverage south of the latitudinal limits of the altimetry missions (81.5 S) this work has combined laser altimeter measurements from GLAS on ICESat with radar altimetry from ERS-1. This combination strategy has maximised the vertical accuracy and spatial resolution of the DEM and minimised the number of grid cells containing estimated elevations. The new DEM contains a wealth of information relating to ice flow, particularly for the two largest shelves, where the effect of flow of ice streams and outlet glaciers can be traced as far as the calving fronts. The image left is a planimetric shaded relief plot of the new 1 km resolution DEM of Antarctica derived in this way. The outer circle shows the limit of ERS data and the improved coverage southward provided by ICESat and the inner circle is the current latititudinal limit of satellite altimeter data.



Annual variation in the geoid for a 6x6 field; (A) cosine and (B) sine component from SLR +CHAMP; (C) and (D) from model GPH4.

Annual and Semi-annual Variations of the Earth's Gravitational Field from Satellite Laser Ranging and CHAMP, University of Newcastle, P Moore, *et al.* Temporal variability in the Earth's gravity field has been estimated from 4 years of satellite laser ranging (SLR) to five geodetic satellites, Lageos 1&2, Stella, Starlette and Ajisai supplemented by over 2 years of CHAMP precise orbital positioning, attitude quaternions and accelerometry. The study considers variability at the annual and semi-annual periodicities in the full field from degrees two through six. Temporal gravity field variability from SLR and from SLR and CHAMP have been computed and compared against geophysical models for surface mass redistribution. Best agreement for the 4x4 field results in an rms geoid difference of 0.76mm with correlation coefficients above 0.85. The semi-annual signal is weaker and less well determined. Results show that CHAMP has a positive effect on the annual variation for a 4x4 field but marginal for an extended 6x6 field. CHAMP has a negative impact at the semi-annual frequency.

A combination of balance velocities with remotely sensed surface velocities on a Svalbard ice cap, Universities of Wales and Leeds, S Bevan, A Luckman and T Murray. The Glacier Aldousbreen was chosen as an example for which recent surface velocities could be compared with a calculated balance velocity and with earlier measurements of surface velocity. The recent surface velocities were quantified using a combination of ERS I-SAR and feature tracking. The computed balance velocities are much less than the observed values and a conservative estimate of the net mass loss from the drainage basin is equivalent to 0.7m/yr water. The evidence suggests that this rate of mass loss may have been continuing for some 25 years.

FUTURE DEVELOPMENTS/STRATEGIC FORWARD LOOK
Plans for future upgrade and expansion of the Facility's capability, as detailed in laser year's report and as endorsed by NSGSC, are based upon upgrade of the laser to **a modern high-repetition rate laser** and the purchase of **an absolute gravimeter (AG) for permanent installation in the basement at Herstmonceux**. Both these upgrades have been funded and the programme underway.

CryoSat (ESA)

New Missions that will require laser-ranging support include **CryoSat**, the ESA ice mission (PI at CPOM, UCL), due for launch in Autumn 2005. From an altitude of 700 km and reaching latitudes of 88°, CryoSat will monitor precise changes in the thickness of the polar ice sheets and floating sea ice. Precise orbit determination will be via the onboard DORIS system, complemented and calibrated using laser range observations.

GOCE, ESA's Gravity Field and Steady-State Ocean Circulation Explorer is dedicated to measuring the Earth's gravity field and modelling the geoid with extremely high accuracy and spatial resolution. A precise model of the Earth's geoid is crucial for deriving accurate measurements of ocean circulation, sea-level change and terrestrial ice dynamics – all of which are affected by climate change. Precise orbit determination will be achieved by an onboard GPS receiver and by laser range observations.

Two **GALILEO Test Bed missions** (SSTL, UK and Galileo Industries) are due for launch in late 2005/early 2006. Orbit validation will be achieved by laser range observations to both satellites.

Longer term, consideration will be given to upgrade of the HERS Ashtech Z12 receiver and antenna, because, as reported above, at times the performance of this important system is sub-IGS standard. It is also considered that a better, highly stable monument for the antenna would be an advantage. In addition, the installation of a third GNSS receiver on site would greatly aid the developing SGF study into local site stability. This may be a collaborative bid to upgrade (with MORP) the two primary IGS receivers in the UK.

Non-Mandatory Facility-specific OPMs: utilisation, allocation of capacity etc **The Operational report will be attached**

SCIENTIFIC FACILITIES & TECHNOLOGY

NERC SPACE GEODESY FACILITY

MISSION STATEMENT

- To make laser range measurements to the special satellites that carry retro-reflectors, according to priorities assigned by the NERC Space Geodesy Steering Committee, and in accordance with international projects and priorities.
- To ensure that the range measurements are of the highest possible accuracy.
- To contribute the data promptly to the international SLR data centres.
- To operate geodetic GPS and GLONASS receivers on the site and contribute the data regularly to the international GPS/GLONASS data centres
- To maintain and develop the software and hardware of the systems in order to give high reliability and to keep the precision of the systems at the current state of the art.
- To achieve a high productivity level of numbers of satellite passes tracked.
- To assist and collaborate with UK analysts in their use of satellite tracking and related data.

In order to fulfil its mission the Space Geodesy Facility will :

- maintain an up-to-date knowledge of international developments of hardware and software in satellite tracking technology
- contribute to the international advancement of the technology, particularly in the areas of orbital predictions, software data processing, and the use of photo-diode detectors
- maintain a constant vigilance for sources of measurement error
- participate fully in UK and international co-ordination of SLR and GPS/GLONASS activities
- carry out data analysis and research, in order to maintain a real awareness of what the users require from the data

User Communities:

The observations from the facility are contributed to international data centres, together with data from other geodetic facilities around the World. The data are used in combination with data from all precise space geodetic techniques by analysis groups world-wide and within the UK for a variety of studies, including oceanography, glaciology, the gravity field of the Earth, tides in the Earth and oceans, a global reference frame, and crustal motion. These data products are used widely by the oceanographic and solid earth science groups within the UK and worldwide.

Membership of the NERC Space Geodesy Facilities Steering Committee

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Centre for Polar Observing & Modelling
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In Attendance:
Dr G Appleby, SGF
Mr. P Gibbs SGF
Dr D Baker, BIGF
Dr R Bingley, BIGF
Dr L. Kay, NERC S&I
Dr D. Holland, MoD
Mr M. Grimmett, BNSC
Miss Kirsty Adam, NERC S&I

Optional Annex: Report on operations for the period 2004 May to 2005 April

1. SLR Observations

1.1 Annual summaries

The replacement of the telescope drive electronics began during September 2004 with a total downtime of some 52 days. Initially the upgrade of the telescope did not go as planned and two subsequent visits by the contractors were required. Much more effort than anticipated was required of SGF staff, particularly the software group, to expedite the upgrade for what is now seen as a major improvement in the operational performance of the telescope. This deeper involvement has turned out to be of benefit as we now understand much more about the electronics, hardware and software subsystems and have the ability to fine-tune them as opposed to having to treat them as black boxes.

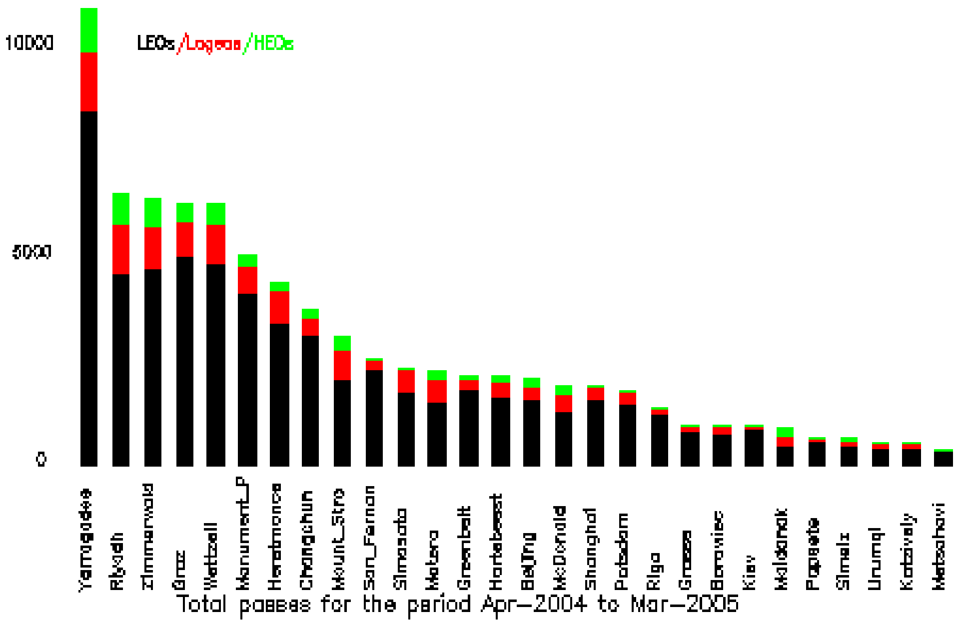
We have ranged to the standard set of satellites, striving to produce a large quantity of high quality observational data. The Table gives total numbers of satellite passes obtained by SGF, categorised according to the prime scientific mission of each satellite. In common with general ILRS priorities, the NERC Space Geodesy Steering Committee recommended that the Facility place the highest priority on the LEO altimetry/SAR satellites, followed by sufficient tracking of the MEO and HEO geodetic satellites to contribute significantly to the maintenance of the global reference frame. The scale and origin of this frame is determined by analysis of laser observations, the orientation by VLBI and GPS.

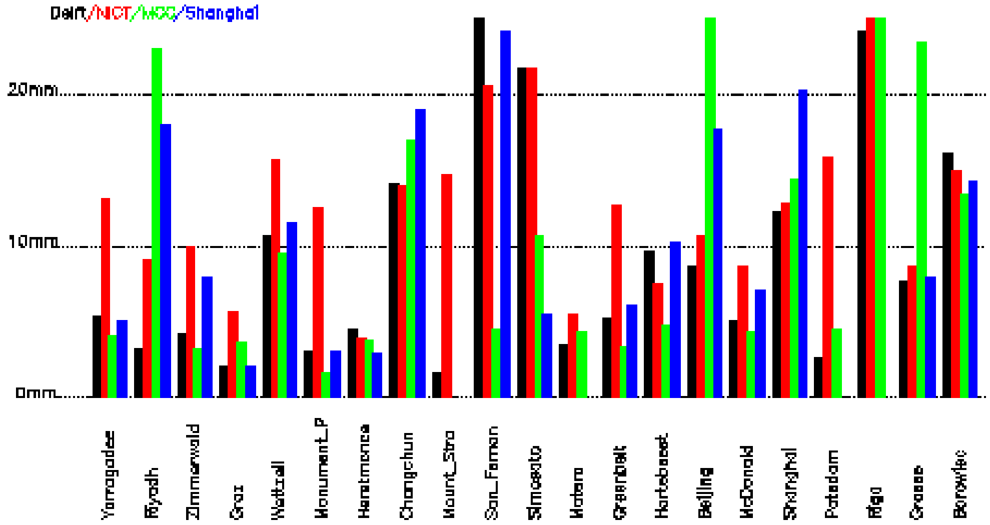
Pass totals for the year 2004 April to 2005 March

Altimetry							
ERS-2	266	Envisat	269	Topex/P	526	Jason-1	477
GFO-1	266						
Geodetic/Gravity							
Lageos-1	438	Lageos-2	298	Etalon-1	32*	Etalon-2	25*
Champ	104	Grace A	76	Grace B	72	Beacon-C	209
Starlette	320	Stella	200	Ajisai	341	Larets	242
Navigation							
GPS35	21	GPS36	22	Glonass	430		
Other support							
Meteor	72	GravityB	56				

* These values are below the norm allowing for the reduced numbers due to telescope upgrade – in a normal year they would be about 75

The two summary plots below are based on data taken from the ILRS quarterly reports and show that SGF makes a major contribution to global tracking both in terms of quality and quality of observations.





Long term stability for Apr—2004 to Mar—2005 from analysis centres

1.2 Observing Schedule

We have also been looking at our current scheduling to demonstrate that it is optimal in terms of efficiency and value for money, taking into account the previously agreed level of support of the primary geodetic and altimeter satellite missions. Options considered in the review included the impacts on cost and data yield of observing solely in office hours, solely in the Lageos 'window', solely in the altimetry window, in the Lageos + altimetry window and for our current scheduling, which is a flexible mix of those options.

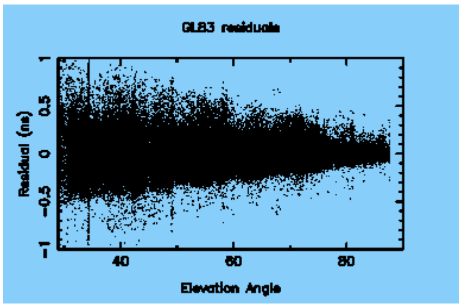
Observing option	GFO-1 Envisat Topex/Jason window	Lageos 1&2 window	GFO-1 Envisat Topex/Jason Lageos1&2	Approx actual schedule For 2004	Office Hours only		
Overtime Required							
Monday	497	530	530	588	0		
Tuesday	483	528	479	563	0		
Wednesday	477	521	524	574	0		
Thursday	486	532	575	598	0		
Friday	548	557	646	495	0		
Saturday	981	1051	1750	904	0		
Sunday	974	1061	1608	898	0		
Total hours	**4447**	**4782**	**6115**	**4624**	0		
Actually Worked				**1820(39%)**			
Passes within above schedules + office hours						No. of passes obtained	% success Par = 34%
Ajisai	1011	1118	1271	1103	326	334	***30
BeaconC	491	554	612	533	115	132	36
Champ	364	375	428	377	122	99	26
ERS-2	794	776	794	760	281	266	35
Envisat	795	777	799	762	280	262	34
GFO-1	911	770	916	785	213	230	*29
Grace	457	463	524	457	125	70	19

Jason-1	1500	1308	1511	1320	384	442	**33
Lageos1	1112	1390	1397	1231	260	429	35
Lageos2	865	1032	1037	898	260	290	32
Larets	703	703	717	692	261	241	35
Meteor3M	847	868	927	879	175	62	7
Starlette	948	1045	1157	998	275	304	***30
Stella	514	545	797	551	131	194	35
Topex	1489	1300	1499	1310	383	499	**38

* Due to Satellite orientation problems
** Jason is more difficult – particularly on the low elevation passes
*** Very easy but always lose out to higher priority satellites

The results of this analysis are given in detail and in summary in the Table above. Within the row labeled 'total hours' we see the number of hours observing that would have to be scheduled to cover the three window options shown in the column headings. As expected, the window that includes all the altimeter and geodetic satellites is the most costly, with the other two options significantly cheaper and similar to each other. What is noticeable is the cost in hours of the actual schedule for 2004, which is midway between the cost of the solely altimetry and solely geodetic windows. We argue that this result confirms that the current scheduling system successfully optimises coverage of the primary missions, acknowledging that in doing so some lower priority targets will receive minimal support when passes fall outside the scheduled window. From the scheduled observing time we actually worked some 39% of the time and managed to obtain data from approximately 34% of the important (and relatively easy) satellite passes. This gives us a “failure” rate of some 10%, most of which is due to variable weather conditions. For the more difficult satellites, this failure rate increases.

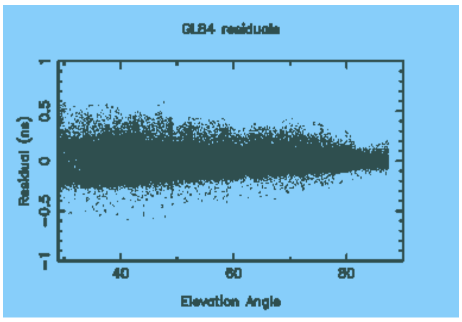
1.3 Glonass observing and analyses.
Obtaining range measurements to the Glonass satellites has become more difficult over the last few years because Mission Control is fitting smaller laser arrays on the modern launches. The arrays are flat panels of reflectors at the base of each nadir-pointing satellite. Thus the apparent area and ‘depth’ of the array varies with elevation, an effect that is apparent in our range measurements and that has been reported in several of our publications in recent years. The relative size differences of the arrays that we have deduced in this way can be seen in the plots below.
To try to ensure a better all round tracking coverage of the Glonass constellation we have now introduced a real-time priority system, which is updated before every observing session.

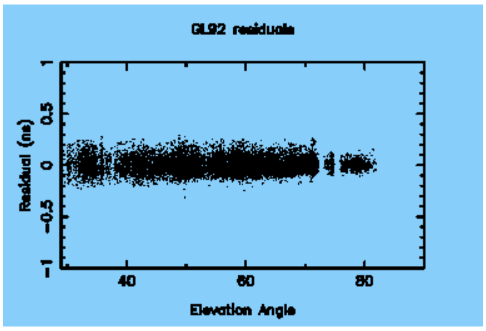


Old style large array – gl83,gl85

Modern small array

Ultra small array – gl92,gl96





1.4 New launches

During the year the US satellite **Gravity probe B** was launched and approved for ILRS tracking by the Governing Board to aid precise orbit determination. Mission Objectives: Gravity Probe B (GP-B) is a drag-free gyroscope experiment being developed by NASA and Stanford University to test two, unverified predictions of general relativity, primarily Lense-Thering frame dragging. (see http://ilrs.gsfc.nasa.gov/satellite_missions/list_of_satellites/gravity_probe/index.html)

Also launched during the period, in December 2004, were three new Glonass satellites (95, 96 and 97), bringing to 14 the total number of active members of the constellation.

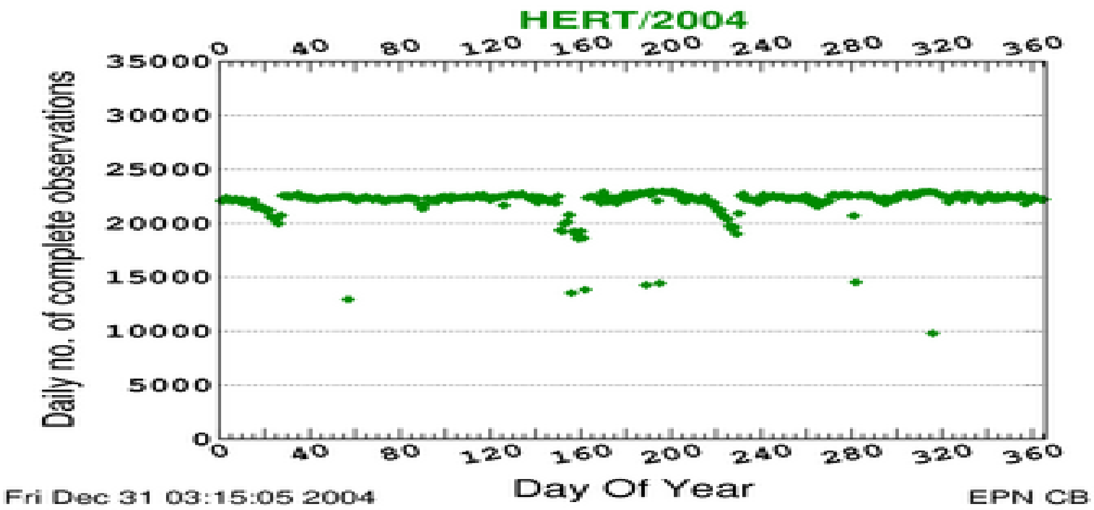
1.5 Global SLR network.

The NASA systems continue working on a reduced observing schedule whilst effort is dedicated to SLR2000 development (http://cddis.gsfc.nasa.gov/slr2000). On a more positive note, it was recently announced to the ILRS Governing Board that NASA is committed to funding its network for the next 5-7 years, and will fund the reinstatement of laser systems on Hawaii and in Peru (Ariquipa), two geographically very useful stations. Both are expected to be operational again by autumn 2005. In addition, an extra observer will join the NASA system on Tahiti.
Yaragadee, the most prolific SLR station of the network, is now funded directly by Geosciences, Australia.
Mount Stromlo has completed its rebuild after the fire that destroyed it and is now operational again.
The Russians announced at the 14th ILRS workshop that they have plans to build one new SLR station every year for the next ten years.

2. GPS and GLONASS Continuously Operating Receivers.

The Ashtech Z12 receiver (IGS station HERS) has continued throughout the period to contribute without any problems daily and hourly 30-second data to the international data centres in support of IGS and EUREF programs. It is worth noting that data from HERS, following an antenna-related problem during 1999-2001, is still treated with caution by the community, despite our assurances that the data is now of high quality and undergoes regular QC at Herstmonceux (see below).

There have been no major problems with the operation of our joint GPS/Glonass Z18 receiver (IGS HERT), which logs 1-sec data, contributes 30-sec hourly and daily data to IGS, and transmits directly via the Internet navigational data for the EUREF-IP real-time pilot project. However, an intermittent fault in the communication between receiver and data logging PC has been looked at. When the system has been running unattended for a long time the number of epochs of data recorded in 24 hours starts to decrease, some packets being dropped in the serial link. The only way to reset the link seems to be to reboot both the PC and the receiver. The plot below, taken from EUREF, shows how the problem affects daily numbers of observations. We have been unable to find a solution that prevents this error happening, having a limited low level control over the Ashtech-supplied acquisition software. However, we have taken steps to make sure that these problems are identified far quicker in the future so the appropriate action can be taken. The number of epochs in a day is now part of the automated QC plots which are checked everyday as well as being available on the SGF website.



In addition the times when epochs were missing show clearly in our own analysis of the HERT-HERS baseline as periods of increased uncertainty in the daily solutions. The baseline plot for 2004 is given below.

We continue to process HERT and HERS data, within the framework of a small European network of IGS sites and have extended this work to include 50 pre-processed global sites. This analysis will contribute alongside SLR analysis in the monitoring of local height variation and has been compared to on-site water table measurements (Appleby and Wilkinson, EGU 2005). The GPS analysis is carried out using the GAMIT and GLOBK software.

Data quality checks are now carried out by differential GPS analysis between the two NSGF sites. Initial baseline time series plots revealed an apparent small error in the data from one of the receivers and similar baseline determination for HERS and HERT to the Belgian IGS site BRUS confirmed that indeed the error appeared only in the HERS data. This problem was quickly solved by cleaning the HERS antenna, indicating the need for continuous rapid quality checks.

The ability to analyse GPS data in house is seen as a major advance in the capability of the group, which at the very least will ensure rapid detection and rectification of data problems.

3. Facility maintenance and development

3.1 Event timer.
Work on the electronic construction of the timing device is nearing completion and it is hoped that the new timer will be ready by summer 2005. The device will eliminate the current need for range-dependent calibration of the existing counters.

3.2 Telescope Drives.
As reported in Section 1, the telescope drive system was replaced over the period Sep-Nov 2004. Initially we had several problems due to under-specification of some components by the contractor, but once replaced with the correct equipment the system has worked very well. The interface between the drives and the observing PC is a card within the PC and this gives us very fast access to the actual drive values. Because of this facility we have been able to monitor in some detail how well the system is tracking. We are still investigating a possible improvement in tracking at high elevations when the velocity and acceleration in azimuth are both very high and rapidly changing. This problem has always been with us but it is only now that we have the tools to monitor in detail the problem.

3.3 Kilohertz Laser.
The new laser is due to arrive in June 2005 and nearly all the mechanical preparations for housing it are complete. It is planned to be able to run either laser for a period of time while we soak test the new event timer. We have therefore developed optical paths for both lasers that will use as many common elements as possible.

3.4 Kilohertz System
Each pulse of the new laser will deliver only some 2% of the number of photons of the current system. New software is being developed to detect the resultant very low data rates in high noise environments so that in real time we will be able to detect the satellite track. Coupled with this is the development of all components of the tracking software – notably new prediction and communication software. As yet we have no software for communicating with the new event timer, but have developed and are using software which accesses the I/O card that will be used for interfacing the timer and therefore see no problem with this stage once the timer is completed. Link budget calculations suggest that operating the new laser at the current repetition rate (10kHz) would yield usable numbers of returns from most targets, thereby presenting a way of introducing in stages the new laser to the operational system.

3.5 Absolute Gravimeter
The gravimeter has been ordered and should arrive in late May (it arrived on June 2). It is planned to house it in the basement below the Facility. This has meant some refurbishment work being carried out, and since this work has been coupled with a general upgrade of the site, which is being managed by NERC Estates management, the area for the gravimeter will not be ready until the autumn. In the meantime we have obtained on a temporary basis an office from Queens University to house the gravimeter.

3.6 Galileo
GALILEO/GSTB V2
The two test bed satellites are being launched this year for systems tests and to occupy the reserved frequencies, otherwise they could be in jeopardy. Thus far, the ILRS has agreed to support the test bed satellites; a request has not yet been made on the operational configuration.
A full constellation of Galileo satellites with retroreflectors could pose a challenge for the ILRS network. The tracking strategy is not yet determined and a subset of stations may be adequate. Continuous tracking may require some dedicated or nearly dedicated stations which would need funding support from Galileo, perhaps on a regional basis. ILRS is actively pursuing this as a potential source of funding for some stations.
During the year, SGF worked with a UK industry-led consortium on a proposal to ESA to manage the ground segment of the test bed work; SGF would host one of the GALILEO/GPS receivers and thus fix its position within ITRF, and carry out laser range measurements probably to the two test bed spacecraft. Laser range measurements would be used by SGF for spot-check validation of satellite radial distance values computed by the consortium from the microwave navigational signals. In the event, the full proposal to include orbital verification was not funded, but it is possible that the receiver will still be placed at Herstmonceux.

3.7 Ranging to 'sensitive' satellites
There is an increasing number of EO missions that are asking for tracking support from the ILRS but which are also carrying sensitive optical detectors that may be damaged by direct interaction with high-energy laser pulses. Usually the dangerous part of a pass is when the station-satellite geometry is such that the laser pulse would directly enter the optical system, such as would occur in the zenith for a nadir-pointing detector. However, with a controlled-attitude system, the danger point could potentially be at any time within a pass. A good example of such a mission is ICESAT, which employs a laser altimeter for land and ice topographical measurements. Currently only a few ILRS stations are trusted by the mission programme (CSR, University of Texas) to make laser range measurements, which are used to validate the GPS-derived precise orbits. Those stations alone are given prediction sets from Texas and a list of times during which it is safe to range.

We have used Gravity-B, which sends out time periods when the retro-reflectors will be visible to stations, to develop our system for selective observing of missions with laser sensitive equipment. Once our system is proven to be fail-safe, we may be licensed to range to truly sensitive missions such as ICESAT and the upcoming ALOS (JAXA) mission, which requires laser tracking for precise orbit determination for its SAR system, but also carries an optical sensor.

3.8 Infrastructure at Herstmonceux
NERC Estates Management has begun a programme of refurbishment of some elements of the Facility, to include replacement of aging electrical systems, installation of double-glazing and central heating. As reported elsewhere, this work will include refurbishment of the basement in order to accommodate the absolute gravimeter.

3.9 Website
The NSGF web site (http://nercslr.nmt.ac.uk/) has undergone a complete overhaul and we believe it is now a very user-friendly site. We would always welcome comments from the committee about the website.

4. International Workshop

SGF is hosting in Eastbourne during the first week of October the ILRS 2005 Fall Workshop – Herstmonceux 2005. This biennial workshop has become a valuable meeting for both practitioners and analysts to exchange ideas and understand the strengths and limitations of laser range data. It is not a formal conference, but sessions on various aspects of the technique and applications will be organised, primarily by convenors of the existing ILRS working groups. SGF staff will be involved both in organising some of the sessions and contributing to most of them. An evening visit to SGF will be scheduled during the week. Matthew Wilkinson is making the local arrangements, and has developed WebPages to aid registration and dissemination of information.

5. SGF Staff

Muriel Ravet joined for a few months from March 2005 as an (unpaid) work experience student having worked at the French SLR station in Grasse. She has been helping us investigate various aspects of our laser and telescope optics, in order that we better understand any losses in the system. This effect will become more significant for the lower power Kilohertz system. Muriel has also taken on a large proportion of the office hours laser observing, which is particularly valuable during this period of development.
G Appleby has been re-elected for two years as deputy analysis coordinator for the ILRS, and thus sits on the ILRS governing board.

6. Publications

April 2005 EGU meeting in Vienna:
The Contribution of ILRS to the International Terrestrial Reference Frame, R Noomen, G.M. Appleby, R. Kelm, C. Sciarretta and P.J. Schelus. *Geophysical Research Abstracts*, Vol. 7, 03136, European Geosciences Union, 2005. Abstract of oral presentation.

Localised and Global Motions observed at the UK Space Geodesy Facility, G.M. Appleby and M. Wilkinson. *Geophysical Research Abstracts*, Vol. 7, European Geosciences Union, 2005. Abstract of Poster Presentation.

The following papers were presented at and appear in the proceedings of the 14th ILRS workshop in San Fernando, Spain in June 2004. The papers may be accessed through the SGF website

New Internal Calibration Target at SGF Herstmonceux; Design and Results. D.Benham, P.Gibbs, V.Smith
(http://cddisa.gsfc.nasa.gov/lw14/docs/papers/cal2_pgm.pdf)

The NERC Space Geodesy Facility: QC possibilities using the routine Long-arc, Short-arc and Time bias processes. P.Gibbs, M. Wilkinson , I Bayer (Degendorf TU)
(http://cddisa.gsfc.nasa.gov/lw14/docs/papers/eng4a_pgm.pdf)

Return Energy Estimates derived from normal point and full rate laser data. M. Wilkinson, G.Appleby, P.Gibbs.
(http://cddisa.gsfc.nasa.gov/lw14/docs/papers/tar1b_mwm.pdf)

Laser ranging as a precise tool to evaluate GNSS orbital solutions. G.Appleby, T.Otsubo(NICT)
(http://cddisa.gsfc.nasa.gov/lw14/docs/presnts/sci7p_top.pdf)

Centre-of-Mass Correction Issues: Towards mm-Ranging Accuracy. T.Otsubo (NICT), G.Appleby
(http://cddisa.gsfc.nasa.gov/lw14/docs/presnts/upg11_gap.pdf)

NERC Space Geodesy Facility Herstmonceux Current Status and Upgrades
(http://cddisa.gsfc.nasa.gov/lw14/docs/papers/tar6a_tom.pdf)

7. Public relations

We have had visits from various astronomical societies and the local cub scout group. We also gave a number of tours of the site during science week and during the Easter holidays arranged through the Science centre. Students and faculty members from the International Study Centre, Queen's University at Herstmonceux are regular visitors to the SGF.
A lecture on space geodesy and the work of the SGF was given to ISC students taking an undergraduate astronomy option. A seminar was given to Section for Earth Observation staff at Monks Wood.

We have also produced a simple publicity leaflet that is available on site and at the Science Centre.

We are involved in the national school work-experience project and take in a few 15-year-old students for a week's work experience during June.