SERVICES & FACILITIES ANNUAL REPORT - FY April 2005 to March 2006

SERVICE	FUNDING	AGREEMENT	ESTABLISHED as S&F	TERM
SGF	Direct from 1999		1994, operational from 1983	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 as an ILRS Analysis Centre 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 and ocean circulation/anomaly dynamics (e.g., Newcastle, 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 (EPRSL, De Montfort), forest vegetation dynamics (CEH).

ANNUAL TARGETS AND PROGRESS TOWARDS THEM

Major upgrade of laser ranging system to kHz repetition rate. This upgrade is driven by the need to increase ranging precision (from 8 to ~3 mm single-shot calibration-board RMS) and greatly reduce satellite target acquisition time, hopefully to a few seconds. The new 10-ps pulse 2kHz laser has been delivered, integrated mechanically and optically into the system and successfully tested at 10Hz in ranging experiments to LEO and to LAGEOS. A great deal of software development has been carried out in readiness for full integration, including migration of many realtime tasks to a LINUX server, new return-detection algorithm, new high-speed ranging and gating software/hardware. Final upgrade to kHz ranging awaits completion of the event timer subsystem, which is being built in-house from ps-level clock units. Once completed, the system can readily revert to using the current 10Hz laser, for example for LIDAR work, whilst maintaining the high precision and linearity of the event timer.

Installation of an FG5 Absolute Gravimeter (AG). The gravimeter has been delivered and many elements tested. Installation in the SGF basement awaits completion, expected during May 2006, of the current major upgrade to the buildings, to include preparation of a safe underground working environment. The OS have committed to surveying several locations in the gravimeter laboratory that will host visiting AGs, including those at POL, for inter-comparison programmes that are important especially for those AGs that are used in the field. The baseline observational programme will be a 24-hour run once per week, initially to study vertical site motion in comparison with the geodetic results (SGF, with POL, UCL). Other programmes are actively encouraged.

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						
Total resource allocation £k	Unit Cost £k			Capital Expend £k	Income £k	Full cash cost £k
	Unit 1	Unit 2	Unit 3			
339				398	220	551

FINANCIAL COMMITMENT (by year until end of current agreement)									
2005-06	120	2006-07	120	2007-08	120	2008-09	120	2009/2010	

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

APPLICATIONS: DISTRIBUTION OF GRADES (Current FY — 2005/06)

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*

	Infrastructure	PAYG		

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 and 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 Modelling of Earthquakes and Tectonics (COMET, Universities of Oxford, Cambridge and UCL), Centre for Polar Observation and 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 (incl. DSTL), British National Space Centre, Surrey Satellite Technology Ltd, Ordnance Survey; European: EUREF; International: ESA, NASA, ILRS, IGS, IERS (International Earth Rotation and reference frame Service).

Publications. A literature search has been carried out to determine numbers of reviewed papers published during 2005 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, Nature and Science. A total of 27 publications for 2005 resulted from this search. Of those, 8 are primarily in oceanography, 3 in global water storage, 8 in solid Earth/gravity field, 3 in polar science, 2 in atmospheric science and 3 in underpinning technology. In terms of NERC strategic priority categories, 12 of these publications discuss Climate Change and 7 concern Underpinning Science. The references to these publications are listed in the Annex to this Annual Report.

OVERVIEW & ACTIVITIES IN FINANCIAL YEAR (2005/06):

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 (mission completed in 2005) 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 Facility, now an ILRS Analysis Centre, continued regular, weekly, computation and combination of SINEX-based solutions for station coordinates and Earth-rotation parameters. The Facility made a significant contribution to the forthcoming **ITRF2005**, by computing 12-year, weekly solutions for onward intra- and inter-technique combination. Several iterations of this product have been carried out.

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 (at a relatively low priority) 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.

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. 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. A poster detailing the HERT contribution to this project was presented at a **EUREF symposium** at BKG, Frankfurt, in February 2006 and is reproduced in the meeting proceedings. A new daily '**state of the GLONASS constellation**' programme has been devised and automated following a request from MoD.

The **Z12, IGS HERS** system continues to supply reasonable-quality 30-second data both hourly and daily to IGS. In-house analysis of GPS data is used to monitor on a daily basis both the quality of the HERS and HERT data and potentially the stability of the site itself within the ITRF frame. This work does show some occasional problems with HERS data, and consideration should 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. Use of an existing suitable site is currently being discussed with the landowner.

COLLABORATIONS: Surrey Satellite Systems Ltd. SSTL asked SGF to laser range to **GIOVE-A**, its in-orbit validation satellite for the **GALILEO** navigation system, in early 2006 following successful launch in December. The ILRS had already responded positively to an ESA request for laser tracking support of the expected two test bed vehicles, but SGF's contribution would be computation of predictions from available approximate orbital elements and refinement following successful ranging. (SGF obtained first ranges in April 2006 and is currently supplying accurate predictions to the ILRS network).

ILRS Fall 2005 Workshop in Eastbourne, UK. SGF hosted the bi-annual 'hands on' workshop in October 2005. SGF staff and ILRS working group coordinators organized Working Group and open sessions; SGF staff made strong contributions to the sessions. Some 65 ILRS associates attended the five-day event, which included an evening visit to Herstmonceux. Presentations are online at http://nercslr.nmt.ac.uk/workshop2005/workshop2005.html

Cambridge University Chemistry Department. SGF is beginning a LIDAR programme, initially using return-rate statistics from LAGEOS to investigate temporal variations in atmospheric transparency at Herstmonceux and at the global laser sites. Working towards a simple LIDAR system at SGF, to work simultaneously with laser ranging activities. One member of SGF staff, who is managing this project, is registered through NERC as a post-graduate student at Cambridge.

University College London, Department of Geomatics Engineering, and **Proudman Oceanographic Laboratory**. The acquisition of the Absolute Gravimeter followed a joint proposal between SGF and POL. A staff member at Herstmonceux who is starting a post-graduate course at UCL will manage its operation.

Newcastle University. Valuable detailed inter-comparison of laser analysis software, to ensure accuracy in modelling and compliance with IERS conventions and standards. The packages have a common root (RGO ORBIT program) but have significantly diverged over the years.

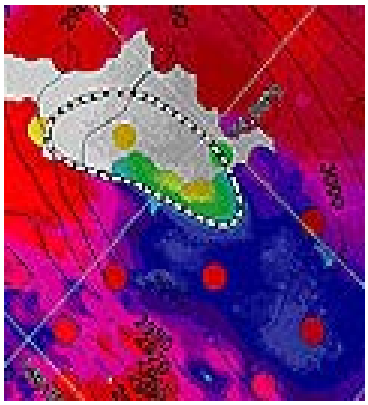
ILRS Analysis Working Group. Collaborating, as an ILRS AC, with research groups from other international institutes towards the up-and-running 'official' weekly ILRS station coordinate and EOP product. SGF is currently submitting weekly solutions that are being combined with five other regular solutions. Co-author of an invited presentation on the work at EGU 2005.

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. Preparation for a joint presentation at EGU 2006 in Vienna.

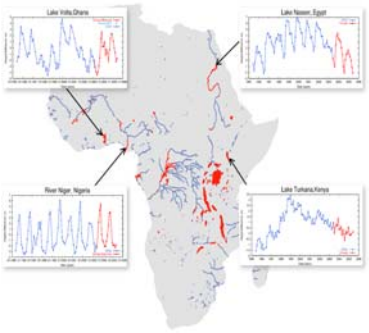
National Institute of Information and Communications Technology, Japan. Continuing the programme on analysis of SLR measurements to the ILRS-approved GLONASS and two GPS satellites that carry laser arrays. Preparation for a poster presentation at EGU 2006 in Vienna, which includes a forward look to GALILEO (**GIOVE-A**) tracking.

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). The photometry system has also been used in an extended programme for MoD.

SCIENCE HIGHLIGHTS (including four most impactful outputs):



Rivers the size of the Thames have been discovered flowing hundreds of miles under the Antarctica ice shelf by their effect on the elevation, observed by ERS-2' radar altimetry and SAR systems, of the surface of the oldest, thickest ice in the region. The finding, by CPOM, UCL, challenges the widely held assumption that sub glacial lakes evolved in isolated conditions for several millions of years and raises the possibility that large floods of water from deep within the ice's interior may have generated huge floods that reached the ocean in the past and may do so again. Previously, it was thought that water moves underneath the ice by very slow seepage. But this new data shows that, every so often, the lakes beneath the ice release floods that travel very long distances. Close inspection of one anomaly revealed an abrupt fall in ice-surface elevation with a corresponding abrupt rise some 290 kilometres away. It is considered that the only possible explanation for these changes is that a large flow of water was transferred beneath the ice from one sub glacial lake into several others. The picture shows an ERS-2 interferogram of ice sheet elevation. Several groups are currently investigating the prospect of drilling down to these sub-glacial lakes where ancient life is thought to exist. However, in light of this discovery, these plans may need to be reviewed since the lakes can no longer be considered isolated systems. D. Wingham, **CPOM.**



Derivation of global river and lake heights in near-real-time from data collected by the ENVISAT RA-2. An automated pilot system is in place to re-track echoes obtained over inland water targets, fuse these results with the IGDR product to obtain atmospheric and instrument corrections and, critically, replace the erroneous level 1B orbit data with the IGDR orbit and derive surface heights. These data are then distributed to researchers via an ESA website. The example plot shows the near-real-time mask over Africa (red parts of the mask denote locations currently producing near-real-time data) together with sample historical time series derived from altimetry from ERS-2 and ENVISAT RA-2. Berry *et al*, **Earth and Planetary Remote Sensing Laboratory**, De Montfort University.

Permanent GPS networks in Europe have been used to investigate the significance of **Glacial Isostatic Adjustment** effects in Europe south of Fennoscandia. It is found that uplift in Fennoscandia is surrounded by subsidence that reaches as far south as the Alps, with a maximum vertical rate of 1.5 mm/yr between 50.5 and 53° N. Horizontal velocity gradients show shortening between Fennoscandia and north-central Europe with strain rates of ~10^{-9} yr^{-1}. There is good quantitative agreement between these results and an existing 3D surface displacement model, although an increase in misfit in the far-field of Fennoscandia suggests that geodetic data outside the uplift area may bring additional constraints to parameters of GIA models. Nocquet, Calais and Parsons, *GRL*, **32,** 10.1029/2004GL022174, 2005.

FUTURE DEVELOPMENTS/STRATEGIC FORWARD LOOK

GIOVE-A (SSTL)

GOCE (ESA)

New Missions that will require laser-ranging support include **GOCE** (2007), ESA's Gravity Field and Steady-State Ocean Circulation Explorer which will measure the Earth's gravity field and model 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. **GIOVE-A,** (SSTL, UK) the first In-Orbit Validation vehicle for **GALILEO** was launched in Dec. 2005. Orbit validation, primarily for onboard clock characterisation, will be achieved by laser range observations. The second validation mission, GIOVE-B (GAIN, ESA) is expected in late 2006. **CryoSat-2**, the ESA ice mission (PI at CPOM, UCL), due for launch in 2008.
GPS/GALILEO/GLONASS receiver for SGF. As an operator of two IGS GPS receivers, a laser ranging system and permanent absolute gravimeter, we should certainly install and manage a GALILEO/GPS/GLONASS receiver, as soon as such receivers become available. It will be important from the outset of the GALILEO system to inter-compare and tie together with GPS, GLONASS, SLR and the other space geodetic systems, and SGF is an ideal site to take a leading role in this enterprise. From a reference frame /geodynamics point of view, the key thing is continuity at a site, so in practice it would probably be best to install another monument for the GALILEO antenna and operate the old and new systems in parallel for at least a year. Ideally, the other IGS sites in the UK, particularly MORP should also be upgraded at the same time.