SERVICES & FACILITIES ANNUAL REPORT - FY April 2006 to March 2007

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 recent installation of an absolute gravimeter furthers progress in this regard.

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, land areas and recently, inland water 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 (CTCD).

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 event timer subsystem has been built in-house from ps-level clock units and the 10-ps pulse, 2kHz laser has been integrated mechanically, optically and in software into the system. This included software migration of many realtime tasks to a LINUX server, a new return-detection algorithm and high-speed ranging and gating procedures. The complete upgrade has been successfully tested in ranging experiments to the full set of laser satellites, from LEO up to GIOVE-A. The single-shot precision of the system has improved to 4mm RMS. The final steps to operational status await electronic safety interlocks to enable the observer full control of the system which ultimately will 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 installed, commissioned and is now fully operational. The OS have surveyed several marked 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 is a ~30-hour run once per week centred on mid GPS-week. 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. From 2007 February, Band 6 reduced to 3.4 FTE.	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				0	200	400
FINANCIAL COMMITMENT (by year until end of current agreement)						
2007-08 250	2008-09 250					

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	PAVG

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 was carried out in order to determine numbers of reviewed papers published during calendar year 2006 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, Transactions of the Royal Society, Nature and Science. Thirty refereed papers were identified, and are listed in the Annex to this Annual Report.
It is known that internationally a very large number of geodesy-related publications result from the global network of operational Facilities, of which SGF is a major component.

OVERVIEW & ACTIVITIES IN FINANCIAL YEAR (2006/07):

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 and GEOSAT Follow-on continued at a high level of priority. For ERS-2, ENVISAT 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 weekly computation 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 as tests continue within the ILRS Analysis Working Group into ITRF scale differences between the VLBI and Laser solutions. SGF work on satellite signatures and Stanford counter effects are becoming very important in this regard. Work is underway to calibrate counters from some of the main stations.

The two vehicles of the **GRACE** gravity mission continue to provide a challenge for SLR tracking and the rapid dissemination of accurate predictions from GFZ is crucial. 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 and also 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.

GPS/GLONASS: The **Ashtech Z-18 joint GPS/GLONASS** geodetic receiver (IGS **HERT**). In common with many other Z-18 systems across Europe, HERT suffered a tracking anomaly in early April 2007 that caused it to lose data for a large part of each day. This error was fixed by changing some internal settings but the receiver remains vulnerable to this type of problem as it is entirely unsupported by the manufacturer. The device also seems to be failing (communication errors typically) more often as time goes by, each time requiring a power cycle and causing data loss. The system remains 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 and IGS real-time GNSS Pilot Projects. Given the recent problems and its importance onsite, a suitable replacement should be sought and modern GPS/GLONASS 'all in view' types would seem to offer several benefits, including the possibility of future upgrade to support GALILEO. Such a device would cost of order £20k

The **Z12, IGS HERS** system continues to supply high-quality 30-second data both hourly and daily to IGS and to BIGF. In-house analysis of GPS data is used to monitor on a daily basis both the quality of the HERS and HERT data and the stability of the site itself within the ITRF frame. This work does show some interesting mm-level, near-annual periodic variations in the HERS-HERT baseline that are under investigation.

ILRS 2006 LR Workshop in Canberra, Australia. Two members of staff attended the workshop and gave presentations on kHz laser ranging, systematic range errors and the LIDAR programme. Three papers will appear in the proceedings. Visits were made to the Stromlo and Yarragadee stations.

COLLABORATIONS:

Cambridge University Chemistry Department. SGF is continuing a LIDAR programme, initially using return-rate statistics from the LAGEOS satellites 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 currently managing its operation is also working on a post-graduate course at UCL. A poster on SLR, GPS and water table analyses and early gravity data was presented at EGU 2007 in Vienna, jointly authored by SGF, POL and UCL.

Newcastle University/POL NERC PhD Studentship. The aim is to be able to quantify the steric component of sea-level change from altimetry, tide gauges and gravity data. It is considered quite speculative and looks at what could be achieved if there were a global network of absolute gravity metres. The study will include analysis of the Herstmonceux gravity data and its connection via station coordinates to the SLR and GPS in order to resolve local and global signatures in the gravity data.

Surrey Satellite Systems Ltd. SSTL asked SGF to compute some laser-based orbits of **GIOVE-A**, its in-orbit validation satellite for the **GALILEO** navigation system, to compare with low precision orbits from the navigational signals. SGF considers such work to have been supported through BNSC's contribution to running costs.

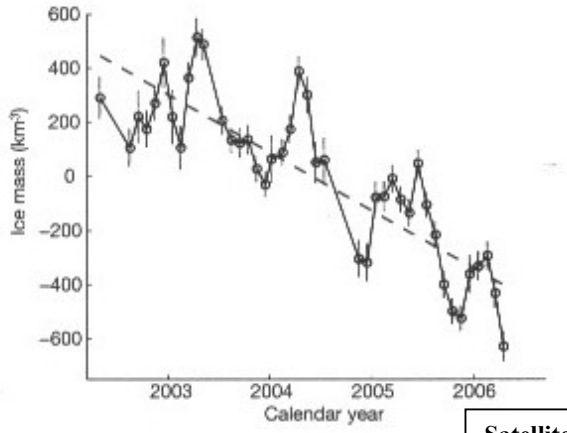
ILRS Analysis Working Group. Collaborating, as an ILRS AC, with research groups from other international institutes towards the up-and-running 'official' weekly ILRS station coordinate and EOP product. SGF is currently submitting weekly solutions that are being combined with five other regular solutions.

ILRS Signal Processing Working Group/ HITU, Japan. Progressing the work towards determination of precise values of centre of mass corrections for the geodetic satellites for the major tracking systems. Preparation for a solicited presentation at EGU 2007 in Vienna.

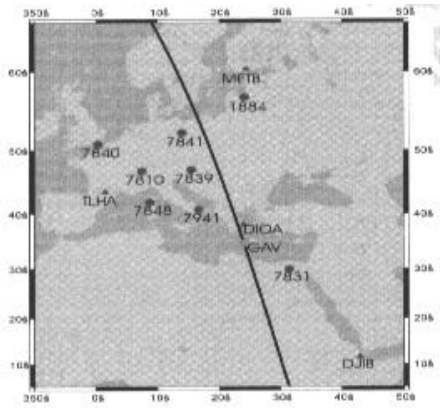
The **photometric capability** of the SLR system continues to be used in an ongoing, 'rapid-response' satellite monitoring programme for MoD. The spin vector work for LAGEOS-2 has come to an end since the satellite is now spinning too slowly for more than a very few and occasional glint observations to be made.

ILRS Governing Board. G Appleby was elected in 2006 as an 'at large' representative, and asked to head the Missions Working Group, which sifts applications from satellite operators for laser tracking support.

SCIENCE HIGHLIGHTS (including four most impactful outputs):



Acceleration of Greenland ice mass loss in spring 2004. A satellite gravity survey using results from *GRACE* from April 2002 to April 2006 has provided an independent estimate of the contribution of Greenland ice mass loss to sea level change. An ice mass loss of 248±36 km^3 yr^{-1}, equivalent to a global sea level rise of 0.5mm yr^{-1} was detected. The analysis made use of LAGEOS SLR results to constrain the J_2 term in the monthly GRACE global gravity field Stokes coefficients. The plot shows the GRACE monthly mass solutions, with a fitted linear trend. The results in this particular plot are not corrected for PGR, but the numerical results above have been corrected. I. Velicogna and J. Wahr**,** *Nature*, 21st Sept 2006.



Satellite Altimeter Waveforms Analysis from a Dedicated Transponder: Precise Height Transfer from Land to the Sea. The distance between the satellite radar altimeter on ENVISAT and an active transponder deployed along the satellite ground track has been repeatedly measured on the island of Gavdos (ground track shown relative to tracking sites in picture left). The transponder return signal can be detected easily in the altimeter data allowing accurate determination of the range at the point of closest approach. Coupled with precise orbital positioning of the satellite using DORIS and SLR tracking in a reduced dynamic solution and precise connection of the transponder to a tide gauge through levelling, it was possible to perform a height transfer between the mainland and the nearby sea surface. The height obtained through the transponder waveforms analysis has standard error 3cm and is in excellent agreement (1cm) with that obtained independently, thus validating the waveform analysis. These results show that the transponder can be used as a convenient tool for calibration and validation of height measurements. E. Cristea, *P. Moore* and D Kucharski, *Transactions on Geoscience and Remote Sensing,* in press.

FUTURE DEVELOPMENTS/STRATEGIC FORWARD LOOK

GIOVE-B (GAIN)

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. The second validation mission for GALILEO, **GIOVE-B** (GAIN, ESA) is expected in late 2007, early 2008. **CryoSat-2**, the ESA ice mission (PI at CPOM, UCL), due for launch in 2008. The ESA solar physics and plasma mission **PROBA-2** (780km, Sun-synchronous) applied in January 2007 to the ILRS for mission support. The need is to enable precise OD for in-flight validation of two new GPS receivers. Questions were raised in ILRS about whether it should support a commercial mission, but tracking was approved. Launch in late 2007.

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 mentioned elsewhere in this report, current problems with HERT suggest a 'soon as possible' upgrade to a modern GPS/GLONASS 'all in view' device that would be upgradeable to receive GALILEO in due course. It will also 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. In practice it would probably be best to install the new receiver at the long-standing HERS location and either move the Z12 HERS system to the current HERT site or use it for further site survey work.