SERVICES & FACILITIES ANNUAL REPORT - FY April 2007 to March 2008

SERVICE	FUNDING	AGREEMENT	ESTABLISHED as S&F	TERM
Space Geodesy Facility, SGF	Direct from 1999	SLA	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 and of the local acceleration of gravity 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 satellite 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 by the SLR system and the two collocated continuously operating GNSS receivers contribute to the definition of a global geocentric reference frame, the ITRF2005 being the most recent realisation: Herstmonceux is one of *ten key worldwide reference stations* that define the origin of this frame. Laser 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 inland water areas, can be reduced accurately using this precise knowledge of the positions of the satellites. Space-based observations of variations in the Earth's gravity field are also becoming increasingly important. 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

Completion of upgrade to kHz laser ranging: The full kHz laser ranging system is now in a working condition, and all satellites have been tracked using it. However, it will not be used in fully-operational mode until a remaining issue is solved; the two lasers of course share transmission optics on the telescope and it is therefore essential that the pulses are co-linear, co-divergent and of the same physical diameter when reaching those optics. These requirements are proving a challenge to achieve and maintain operationally, with the result that daytime operations in particular are problematic. Investigations to resolve the situation are underway, including a study into a new detector (MCP) that should greatly improve the signal-to-noise situation, plus enhancement to the camera system that permits a visual image of the back-scatter from the laser to aid pointing adjustments.

New receiver for station HERT: The Ashtech Z-18 system HERT suffered a tracking anomaly in early April 2007 that caused it to lose data for a large part of each day. Given this and other problems and its importance on-site, a suitable replacement, a modern GPS/GLONASS 'all in view' Leica GRX GG Pro, which includes the possibility of future upgrade to support GALILEO, has been purchased in collaboration with GEF. After a period of testing on the OS pillar close to the Station, the GRX is now fully operational. It generates standard RINEX data as well as streaming navigational data via the Internet in support of EUREF and IGS real-time programmes. It is now timely to consider an upgrade to the long-running, primary HERS Z12 system.

SCORES AT LAST REVIEW (each out of 5)		Date of Last Review: 2008		
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	Contract Ends
100 %	Staff & Status 1 at Band 5, 3.4 at Band 6, 3 at Band 7	(January) 2013	(31 March) 2014

FINANCIAL DETAILS: CURRENT FY						
Total Resource Allocation £k	A unit cost has not been estimated for this Facility			Capital Expend £k	Income £k	Full Cash Cost £k
407	Unit 1	Unit 2	Unit 3	56	100	450

FINANCIAL COMMITMENT (by year until end of current agreement) £k				
2008-09 400	2009-10 400	2010-11 400	2011-12 400	2012-2013 400

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

APPLICATIONS: DISTRIBUTION OF GRADES (Current FY — 2007/08)

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 absolute gravimeter data is in a different category since it is being used primarily at present in collaboration with UCL and POL; in the longer term it is likely that the data will be made available to other research groups on request.

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 and who therefore will be users either directly or indirectly of SGF products. Here, at present, the data from the absolute gravimeter is treated as a special case, being available only to SGF, POL and UCL. 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 Oceanographic 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) and emerging Global Geodetic Observing System GGOS, an overarching Service of the International Association of Geodesy.

Publications. A literature search was carried out in order to determine numbers of reviewed papers published during calendar year 2007 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. Some 17 refereed papers were identified.
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 (2007/08):

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, as an ILRS Analysis Centre, continued weekly and began during the year **daily** computation of solutions for station coordinates and Earth-rotation parameters, for input to the rapid results from the IERS. Tests continue within the ILRS Analysis Working Group into ITRF2005 scale differences between the VLBI and Laser solutions, with SGF work on satellite signatures and Stanford counter effects becoming very important in this regard. Work is underway to calibrate counters from some of the main stations, with counters from San Juan and Changchun likely to be sent to SGF during 2008.

The two vehicles of the **GRACE** gravity mission continue to provide a challenge for SLR tracking, but 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; SGF and others' analyses suggest that there are still unresolved radial differences of about 20mm between laser range measurements and distances computed from IGS orbits. GIOVE-B was launched in April, but this time the Yaragadee station was first to obtain returns.

GPS/GLONASS: The **Ashtech Z-18 joint GPS/GLONASS** geodetic receiver (IGS **HERT**) has been replaced by a GPS/GLONASS 'all in view' **Leica GRX GG Pro** receiver. Following a period of testing on the OS pillar midway between HERT and HERS, the new receiver was set operational on 2008 January 25. Analysis work using all three receivers for short-baseline studies, including some interesting mm-level, near-annual periodic variations, was presented in a poster at EGU 2008 in Vienna. 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.

Absolute gravimeter: The instrument continues to work extremely well in a programme to obtain a series of mid-week, 24-hour averaged gravity values for comparison with the space-geodetic site motion solutions. The gravimeter was used at a European inter-comparison workshop in Luxembourg in late 2007, and early results suggest that it is working to spec with no systematic problems greater than 2 μGal relative to the other 18 or so systems at the workshop.

ILRS 2007 technical workshop in Grasse France. Matt Wilkinson and Graham Appleby attended the workshop and gave presentations on kHz laser ranging and systematic range errors, and attended various Working Group meetings, including running a Missions WG session.

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. Work progresses to build a single-channel LIDAR system at SGF, initially to work separately from the laser ranging activities. A PMT has been purchased and software and mechanical integration continue. Christopher Potter, who is managing this project, is registered through NERC as a post-graduate student at Cambridge.

University College London, Geomatic Engineering Department, and **Proudman Oceanographic Laboratory**. V. Smith, who is currently managing the operation of the SGF gravimeter, is working on post-graduate work with UCL, POL and SGF. A poster on SLR, GPS, AG and water table analyses was presented at EGU 2008 in Vienna, jointly authored by SGF, POL and UCL, and a more detailed analysis is underway, initially for a paper to be presented at an IAG gravity field Symposium in June 2008 in Crete.

Ordnance Survey. The OS is building a UK network of some 12 GNSS geodetic sites, ideally placed on bedrock. Despite the lack of bedrock at the Herstmonceux site, OS remains very interested in locating one of its receivers close to the multi-technique station. Site visits and discussions will take place during summer 2008.

IGN, France. An Institut Geographique National (Paris) survey team is carrying out measurements of local inter-technique ties at some of the major geodetic stations that contribute most to the definition of the ITRF. The team offered to do a survey at Herstmonceux, and carried out the work in late June 2008. The results are awaited with interest, particularly as a comparison with the currently-adopted vector between HERS and the laser fiducial point.

ILRS Analysis Working Group. Collaborating, as an ILRS Analysis Centre, 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. In a new departure, a subset of the ILRS ACs, including SGF, are computing daily solutions following a request from IERS to provide results for its 'Rapid' Earth orientation solution.

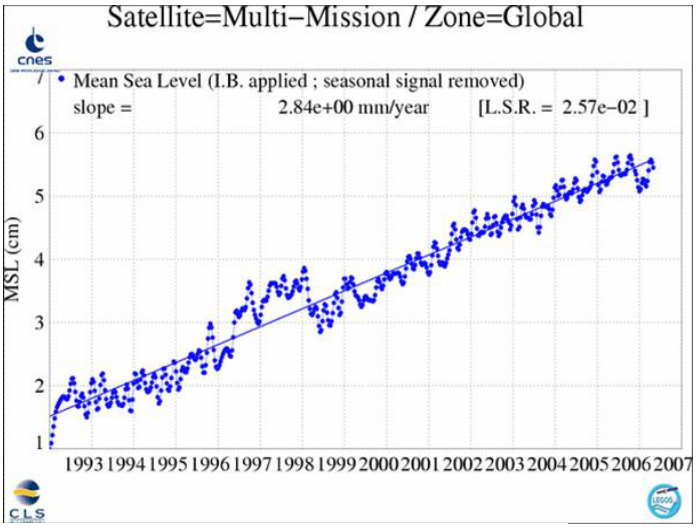
HITU, Japan. Finishing the work towards determination of precise values of centre of mass corrections for the geodetic satellites for the major tracking systems. Preparation of results for the next laser ranging workshop and to provide a table on the ILRS website for use by all analysts.

The **photometric capability** of the SLR system continues to be used in an ongoing, 'rapid-response' satellite monitoring programme for MoD. In a new venture, the on-site 40cm reflecting telescope has been used to build an automated photometric capability to support a long-term monitoring need; the system has the advantage that it can be used totally independently of the SLR operations.

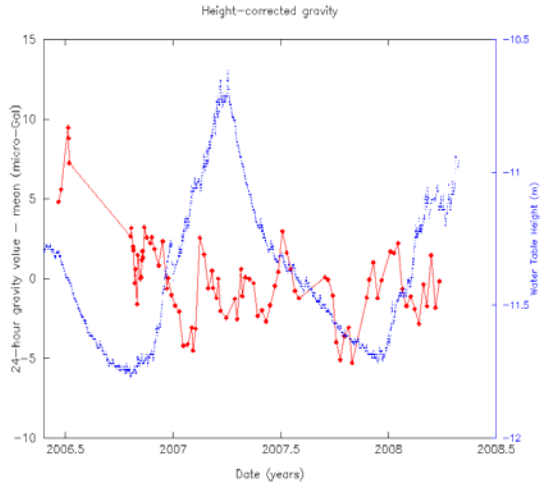
ILRS Governing Board. G Appleby continues as an 'at large' representative, heading the Missions Working Group which sifts applications from satellite operators for laser tracking support. Recent successful applications include JASON-2, GOCE, Tan-DEM-X and Lunar Reconnaissance Orbiter (LRO).

Anniversary. March/April 2008 is the 25th anniversary of the first laser returns at Herstmonceux, from STARLETTE and LAGEOS. The system was fully operational, day and night, by 1983 October.

SCIENCE HIGHLIGHTS:



Sea Level monitoring from space. The successful launch in June 2008 of JASON-2, the CNES/NASA altimeter satellite, ensures that into the next decade sea level will continue to be monitored on a global basis and at high precision. The plot (left) shows a multi-mission (TOPEX/Poseidon, JASON-1, ENVISAT) solution for global sea level change over a fourteen-year time span. Key to the ability to determine small sea level changes with minimum corruption from systematic error, including satellite orbital error, is both precise ground- and space-based tracking of the satellites themselves and the maintenance of a global terrestrial reference frame at the mm-level of precision. Multi-technique tracking stations such as SGF provide laser tracking of all the altimeter satellites and provide fixed ground stations for GNSS in order that the GPS orbits are well-defined. In turn, this work leads to precise orbit determination of the altimeter EO satellites. Such stations also provide the means to precisely monitor via GNSS the vertical land motion at tide gauges which are also used to monitor sea level changes and to calibrate the altimeter measurements themselves. Sources include 'Climate Change 2007; the Physical Science Basis, Report of the Intergovernmental Panel on Climate Change (IPCC 2007), CU Press.



Early absolute gravimeter results at SGF, Herstmonceux. Nearly two years of weekly gravity values of precision better than 1μGal have been secured and preliminary analysis carried out. Vertical site motion determined from in-house laser and GPS analyses have been removed from the gravity data in an attempt to understand local effects on observed gravity changes. The plot (left) shows the time series of weekly gravity data (red) plotted against water-table depth (blue). The (lack of) correlation is the subject of further study into, initially, soil-moisture effects for which a detailed understanding of the local geology will be required. Such effects are likely at many geodetic facilities.

FUTURE DEVELOPMENTS/STRATEGIC FORWARD LOOK

New Missions that will require laser-ranging support include **GOCE** (2008 Sept.), 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. 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) was launched in April 2008 and will require sporadic-campaign laser tracking. **JASON-2**, the follow-on to the highly successful TOPEX/P and still-operating JASON-1altimeter missions will be launched in 2008 June and will require as much laser tracking as possible. JASON-2 also carries the Time Transfer by Laser Link (T2L2) system which will provide a precise characterisation of the on-board DORIS clock by one-way laser tracking by stations that have high-quality frequency standards, e.g. H-Masers. **CryoSat-2**, the ESA ice mission (PI at CPOM, UCL), is due for launch in 2009.

Upgrade to accuracy of system time and frequency Observations made at the Facility, both laser and GNSS, are currently time-tagged using GPS time. The accuracy of the UTC epochs determined in this way is of order 100ns, which is adequate for standard analyses of the laser and the GNSS data. However it would be advantageous to increase the accuracy and stability with which UTC is realised at the Facility and a high-accuracy, very-stable-frequency H-maser is planned to be installed to derive station time and as a source of the 10MHz required by the event timers and in particular the GNSS systems. This upgrade will also enable a full part to be taken with the upcoming **t**ime transfer by laser ranging on the JASON-2 mission, due for launch in 2008 June. This experiment has the potential to monitor the on-board DORIS oscillator and thus improve the precision of that technique to the benefit of in particular the altimeter data.

Non-Mandatory Facility-specific OPMs: utilisation, allocation of capacity etc

The laser ranging system is operated, weather-permitting, on a 24-hour, seven-days-a-week flexible principle that takes account of ILRS and Steering Committee priorities. Additional ranging activities are carried out according to requests from the co-funding partner. In practice, some 35-40% of available passes are tracked, placing the Facility in the top 10 of 25 or so contributing ILRS stations. The GNSS systems work continuously, and at present the gravimeter is operated for one 24-hour period once a week. Further demands on the gravimeter could thus be accommodated, but with a subsequent reduction in time between services, currently estimated to be at two-yearly intervals.