Global Climate Change – Plans for a 15-year Space Odyssey

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A unique opportunity has arisen for a revolution in how we view our planet from space. It is an opportunity that will allow UK Government, science and industry to play a leading role.

Between 2013 and 2016 Iridium Satellite LLC[1], a US company, needs to replenish its constellation of 66 low Earth orbit communications satellites for operation to 2030 and beyond. The constellation is arranged in 6 polar orbit planes of 11 satellites (see front cover) giving complete global coverage, all the time. In September 2006, Trident Sensors suggested that the next constellation might host Earth observation sensor payloads. Since then, Iridium and Trident have worked together to look at the feasibility of this idea. This includes an assessment of current priorities for Earth observation, their societal benefits and fit with political priorities, the identification of candidate payloads and their manufacturers, consultation with the scientific community and production of a business plan.

This is a true revolution in how missions are conducted, a move away from R&D-driven, single satellite, one-off missions to fully operational, continuous observations. The most important issue facing us is global climate change and in particular obtaining long term continuity in measurement of the processes that influence it. These include the accurate knowledge of the Earth's radiation budget, understanding climate dynamics and monitoring of the air-sea interactions that drive our weather system. The broader benefits to society required of Earth observations were presented by the Group on Earth Observations (GEO) in the GEOSS 10-Year Implementation Plan[2]. The key themes and the functions are summarised in the first two columns of Table 1.

Due to the short time scales (see Figure 1), a high degree of readiness is essential, so heritage instruments will be flown, that is, ones with space-proven track records. Reviews by Trident, GEO and ESA have reached a consensus on four suitable payloads (see Table 2) that match all the criteria concerning priorities, themes, social benefits, heritage and the strict payload specification (50kg weight, 30 x 40 x 70cm dimensions and 50W average power consumption).

Table 1. The Group on Earth Observations - Themes and Function [2]

THEME	FUNCTION	INFORMATION FROM SENSOR DATA
Agriculture	Sustainability & desertification	Land use & change of use; drought; crop diversity
Biodiversity	Monitoring & conservation	Loss/change of habitat (e.g. coastal, terrestrial, ice)
Climate	Variability & change	Air-sea interactions; clouds; moisture content; global climate change models
Disasters	Natural & man-made	Tsunami & extreme weather early warning; wild-fires; response & remediation
Ecosystems	Management & protection	Fisheries; ocean colour; forest canopy
Energy	Management of resources	Sea state; tide & wind for renewable energy
Health	Environmental factors & security	Monitoring marine pollution; crop management
Water	Resources & global cycle	Ice loss; sea level change; ocean currents
Weather	Forecasting & warning	Invaluable data set in real-time for accurate forecasting

Table 2. Sensor Payloads (at time of publication)

SENSOR	QTY	MEASURED PARAMETER(S)
Altimeter	24	Wave height, wind speed; canopy height; ice height
GPS Occultation	12 (66)	Atmospheric water vapour & temperature soundings
Imager	6 (18)	Multi-spectral for ocean colour & land imaging
Radiometer	24	Earth radiation budget; energy source for the climate system

Figure 1 SCHEDULE

Dec 2007 - ***EO Mission Definition and Agreement***

June 2008 - ***EO Programme Initiation and Commitment to fly EO Payloads***

Sept 2008 - ***Iridium Contracts with Primes***

Jan 2009 ←→ **2013** - ***EO Payload Development & Integration with Satellites***

2013 ← ***12 Launches*** → **2016**

2016 ← ***Fully Operational for EO Data*** → **>2030**

Brief summaries of what the sensors measure and the number of each type to be flown in order to optimise the data coverage are given in Table 2. The four missions will produce a powerful, coherent, data set that will provide valuable information on a plethora of environmental parameters as listed in the third column of Table 1, cross-cutting all the GEO themes.

Taking each mission in turn, the altimeter uses radar to range to the Earth's surface. Sea surface height can be measured to 5 to 10 cm at the first pass of data processing then to 2 to 3 cm with incorporation of accurate knowledge of the satellite's position as given by onboard GPS sensors. The constellation of 24 altimeters will give unprecedented coverage of coastal and ocean waters, including information on open ocean currents, the change in ice fields and Tsunami early warning. Real-time data will be of value to fisheries, shipping and insurance markets.

The GPS Occultation sensors intercept radio signals from the GPS satellite network. These signals pass through (are occulted by) the atmosphere close to the horizon and so take a path through a deep cross section of the atmosphere. Variations in electron density and air density, a function of temperature and moisture content, bend the signal and slow its speed. By measuring these shifts in the signal, scientists can determine the atmospheric conditions that produced them. The result: profiles or soundings along thousands of angled, pencil-like segments of atmosphere, each about 200 miles long and a few hundred feet wide. The general consensus is that as many as possible of these sensors should be deployed, hence the option to fly 66. The benefits include: high accuracy temperature measurements around the globe for climate models, long term variations in temperature and their input into models, good data over the poles and open oceans where weather balloons are not used, high quality water vapour measurements for forecasting hurricanes, typhoons and violent storms and improvement in the reliability of weather forecasting.

The aim of the broadband radiometry is to determine the variation in the Sun's output and how this impacts on the terrestrial climate. These data are of greatest importance to climate change models, as the Sun drives the Earth's climate system and small changes in solar energy can have a dramatic effect on climate. For example, it is estimated that the change in solar activity is responsible for a 0.2°C rise in temperature over the last 150 years. Although the input of energy from the Sun is well understood, the amount of radiation leaving the planet is not and it is a very complex system. This data also will help improve weather forecasting.

A multi-spectral imager that will use between 6 and 16 discrete wavebands in the UV-visible is under consideration. The measurement of ocean colour gives information on phytoplankton, suspended solids, coastal erosion and pollution and their relationship to eddies and data can be used to estimate biological production. Also these instruments can image clouds, detect wild-fires (eg Greece recently), help in disaster management and monitor desertification, deforestation and land usage.

The missions need to complement existing or planned Earth observation programmes both on the Earth's surface and from space. Iridium's core business is communications and currently the network is used to transmit data from, for example, ocean drifters and maritime and terrestrial meteorological stations. Scientists receive data within 20 seconds, irrespective of the remote station's position on the planet. An advantage of the new constellation is that data from the ground platforms will be transmitted to the observing satellite overhead allowing for real-time calibration of sensors. This opens up the possibility of now-casting of extreme weather events. The missions will complement others such as ESA's Sentinel series and those planned by NASA[3]. Furthermore the 15-year life of the constellation assures data continuity where many space missions have a lifetime of typically <5 years and where repeat launches are both expensive and not guaranteed.

The space industry at home and abroad has been consulted and indeed the Request for Information for the satellites was issued in July 2007. The international political and scientific interest is gaining momentum. GEO, BNSC, NASA and NOAA have set up working groups to review the payloads, including other options such as atmospheric chemistry, space weather, and cloud vector monitoring.

The GEO Executive, based in Geneva, is actively seeking the opinions of the international community through various channels. The project was mentioned at a recent meeting hosted by UNESCO in Paris[4] and will be tabled for consideration by the GEO Ministers and Agencies at the Summit in Cape Town in November 2007.

The total cash budget **for the whole of the Earth observation segment**, including the purchase and integration of all the sensors, their launch, data retrieval and dissemination, from start of funding in 2009 to 2030, is estimated at ~£800M, equivalent to £0.58M per satellite per annum. In space terms this is staggeringly good value for money because operational science is underpinned by Iridium's commercial space and ground infrastructure investments. A 7-year plan (2009-16) to cover all costs, including the pre-buy of data through to 2030, is under consideration which will free the community from the vagaries of funding and inflation after 2016. As Public-Private Partnerships go, there can be absolutely no slippage in the schedule because Iridium must have continuity in connectivity for its communications business.

The proposal meets all the priorities of the Space Studies Board[2] for Earth observation: contribution to the most important scientific questions; societal benefits (application and policy); contribution to long-term observational record; how it complements other observational systems; degree of readiness (technical, resources, people); affordability (the mission and annual support); risk mitigation and strategic redundancy; cross-cutting other themes.

However, to reinforce comments made at the PSC briefing on satellites in November 2006[5], the UK is in a very strong position to tender for space contracts. The Iridium and Earth observation hardware business alone is >£1B for the build of satellites and sensors and the 12 launches. In addition to this is the delivery of the second level ground segment in terms of data retrieval, calibration, quality control and dissemination.

The Government has a key role to play in the support of not only the UK space industry, where it may provide the mainstay of a national space focus at the top level of government[5], but also the science community, in the provision of data for the development of climate models in which the UK is a world leader through the efforts of NERC and Met Office scientists. The development of business around value added products for the maritime and service industries should be encouraged. Then there is the kudos of taking a lead on the international stage. With the benefits comes the responsibility of Government to commit to the opportunity on a timescale consistent with deployment of the commercial venture (Figure 1).

Moreover, there is a higher purpose for the support of this programme. Unlike the "one giant leap for mankind" that was motivated by the Cold War, the objective here is to bring to fruition a vision that really will touch all of mankind – every man, woman and child on the planet – in being proactive to the effects of global climate change, with an outreach that transcends geo-political boundaries. "These are extraordinary times. And we face an extraordinary challenge." – Kennedy's words from the address that announced the Apollo programme[6]. These too are extraordinary times and this is a unique chance to meet the challenges of global climate change.

REFERENCES

1 see www.iridium.com

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