Knowledge Transfer in Space Science

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Abstract Knowledge Transfer (KT) is a major part of technical aspect in space science. By involving the research council funded Knowledge Transfer Account (KTA) programme and the university industrial and commercial partners, these strengthen the future research collaboration amongst the university, industrial, commercial, scientific and engineering communities. Since the space science research and development is a multi-billion pounds sterling industry, it is often referred as the most advanced research and technological breakthrough. The industry inventions including scratch-resistant lenses, smoke detectors, cordless tools, water filters become the popular industrial products. They benefit us enormously.

This paper is to present the Future Universities and Future Knowledge Systems for KT in space science. It includes the discussion of the European Union (EU) Seventh Framework Programme (FP7) and its e-infrastructure projects, Astrogrid Virtual Observatory, Gaia Data Centre, European Space Agency (ESA) XMM-Newton Satellite Reflection Grating Spectrometer and Optical Monitor, National Aeronautics and Space Administration (NASA) Swift Explorer mission UltraViolet/Optical Telescope, Hinode Extreme UltraViolet (EUV) imaging spectrometer, Near Infrared Spectrograph (NIRSpec), Cassini Electron Spectrometer (ELS), CryoSat-2 mission simulation and EnviSat radar altimeter, GlobIce, SOHO, Cluster-2, ESA's Exobiology on Mars (ExoMars) Panoramic Cameras (PanCam) and stereo mapping plus many future space missions in the pipeline.

The United Kingdom (UK) Government's Engineering Physical Science Research Council (EPSRC) and University College London (UCL) develop the programme of exchanging knowledge via their KTA. The account itself has a wide range of industrial and commercial partners. The aim of the programme is to attract the highly skilled people and the high-tech industries (such as space industry) to innovate and to develop the opportunities in the industrial/commercial fields and value added market. All these can be achieved with the collaboration and KT in the Future Universities and Future Knowledge System.

Introduction

Before the internet, the industrial revolution was built upon the factory models. It had bureaucracies, one-to-one knowledge passing, individualism, elitism, selection for the few and basic skills for the many. However, since the information age and World Wide Web start; these changes to knowledge build/exchange/transfer for all, collaborative, lifelong learning or continuous professional development (Keating, 1996).

Recently the (Williamson, 2010) article shows the ESA's technology transfer approach for new funding and support towards space entrepreneurs. Technology networking, connection and catalysis are the theme of this initiative. The UK Space Agency and venture capital are providing €100m funds to meet the space company start-up costs for their "delivery partner for telecommunications and navigation programmes" and the Open Skies Technology Fund. There will be 372 space technologies available, e.g. ultrasound technology, slush-hydrogen, carbon dioxide isotope ratio meter and tunable laser absorption spectroscopy. The (Cowper, 2002) paper states that there are the exponential expansion of our knowledge, the increase of knowledge system complexity and all these need to be managed properly for KT.

KT is the UCL research top priority for collaboration with industries. Using the knowledge gains from the research is important for product innovation. It allows the research and development timescale to be shortened. By transferring the know-how to manufacture the finished product without the initial investment costs, the company will often benefit from such approach. Over the years the space science research is the exemplary result for KT between the research institution and industry. Especially in the space science research and development, there are the vast information and data to be shared among the multi-discipline applications. Future knowledge system such as Generic Data Processor (GDP) will appear as the possible solution.

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XMM-Newton Satellite, Swift Explorer mission, Hinode imaging, Cassini instrument, CryoSat-2 earth observation and EnviSat altimeter, Cluster-2 and SOHO projects; these are some of the examples of space mission running at Mullard Space Science Laboratory (MSSL), UCL. These missions generate huge amount of information, innovation and knowledge. In order to collect the information and to construct the knowledge infrastructure, the EU decides to fund the FP7 programme and its e-infrastructure. The idea behind this innovative approach is to encourage KT within space science and to allow other industries to utilize the collected information for their research and development. The main objective is to focus on the applications benefit for mankind, sustainable development for science, information and knowledge. For example, e-infrastructure provides the better opportunities for space related industries and geo-information service to improve access to the data knowledge for services such as global monitoring for environment and security. The EU is willing to invest to maintain technological know-how as well as knowledge in science and space exploration, through the international collaboration likes International Space Station. FP7 encourages us to develop a more coordinated, transparent and coherent approach.

Dissemination actions are included within the FP7 e-infrastructure. In particular, activities for promoting the collaboration, technological KT, coordination and support actions such as contribution for science education, research and outreach are encouraged under this directive. The key important issue in here is the investment return through the knowledge driven economy and increasing public awareness of the results achieved. For example, in the UK along the space science is a £7 billion industry in turn of the annual gross domestic product index. It has the potential to expand to £40 billion a year business known as the recession-proof industry. Other example is for the KT relating to the agriculture world-wide. The FP7 e-infrastructure adopts the appropriate policies for the sustainable food development and planning. The forecast yield knowledge is exchanged among nations. The earth observation data knowledge is transferred as the agricultural statistics and is made available for the industry and retail outlets.

The FP7 e-infrastructure goals include the service providers and partners for the establishment of a platform where they are able to exchange knowledge, new partnership for the development of innovative products is generated including up-to-date information about financing opportunities. Therefore, it is expected to improve the knowledge, structuring, awareness of market, to assess market segments suitable for investment, to identify potential partners and to provide with a capacity to respond to the needs. Any activities generated from the FP7 e-infrastructure should stimulate the industries growth. The networking approach is also expected to have the positive impacts on dissemination of information and KT. The FP7 e-infrastructure programme should enhance the effectiveness and productivity of the scientific and industrial communities, and promote the contribution of scientific and technological knowledge (FP7, 2009), through

- mobilizing the best expertise, in particular academic researchers and scientists, in various fields of science for the analysis of data and interpretation of knowledge, selecting the most innovative and challenging objectives in emerging scientific fields;
- extending the usage of available knowledge and archived data, and promoting its transfer to educational bodies, as well as the general public;
- developing better tools to process, access, archive and distribute data and knowledge obtained from different sources such as virtual observatories.

For example, Virtual Atomic and Molecular Data Centre (VAMDC) is one of the EU FP7 projects to create an e-infrastructure for the exchange of atomic and molecular data. This typical KT project involves 15 partners representing 24 teams from EU member states, Serbia, the Russian Federation, Venezuela; external partners from USA and Far East. VAMDC aims for providing a world-wide spectrum of atomic and molecular e-science to the users whom include scientists, physicists, engineers and general public with the interests of atomic and molecular physics. VAMDC is a true KTA for the networking, service and joint research activities. Through the encouragement of the EU FP7 e-infrastructure, the UK EPSRC and UCL KTA programme we have the opportunity to expand and to present the other KT cases in space science at the following sections.

Virtual Observatory Software for Astronomers (AstroGrid) is a European project to enable astronomers and scientists finding resources within the community. It follows the International Virtual Observatory (VO) Alliance standard. AstroGrid community collaborates on technology, data and support with other users. It manages knowledge and information, shares ideas and technology exchange between partners. AstroGrid can handle images from data centre and transfer files between users. It provides many useful tools including VO Deskop to search resources and query data, Topcat for data presentation and AstroGrid Python for users writing their own scripts. AstroGrid is using the client/server methodology as its engine. On the client side, users can run the Astro Runtime software on their laptop or personal computer. On the server side, it has the infrastructure of community service, resource registry, virtual data storage space and sequence of workflow tasks. All these are remote accessible as the universal worker service. Applications such as the cross matching catalogues can be easily achieved. Suggested KT activities include grid software and client/server applications.

Graphical Astronomy and Image Analysis (Gaia) an ESA spacecraft will launch in 2012. It has the capability to map the entire Milky Way Galaxy in 3D. About one billion stars will be included using the positional and radial velocity measurements stereoscopy. On-board the satellite will have the multi-colour photometry. MSSL will produce the software for the radial velocity from the Gaia spectroscopic data which will include extragalactic objects, supernovae, exoplanets and many other solar systems. The Gaia data centre will use the supercomputers to provide the large amount of observational data which will become available after ESA launches the mission. Recommended KT tasks are 3D applications, images database and supercomputer technology.

XMM-Newton truly follows the footsteps of Isaac Newton in building the first practical reflecting telescope. It carries three onboard X-ray telescopes and two Reflection Grating Spectrometer (RGS) that MSSL is the main contributor. Two X-ray telescopes have an array of reflection gratings placed in the bean at the X-ray mirrors. The grating reflects half of the X-ray to nine Charge Coupled Devices (CCD) detectors array from the telescope focus and the remaining half goes to the European Photon Imaging Camera. The CCD provides a very accurate measure of energy of the input X-ray and photon. To measure the objects distance away with high energy spectrum, an optical monitor takes both the X-ray and optical/UV wavelengths including visible, Ultraviolet and X-ray. The KT opportunities consist of spectrometer, CCD, X-ray and UV applications.

Swift Mission a successful NASA mission-by-accident from the cold war, since then gamma-ray bursts have become a major strand of research. These spectacular explosions are caused by the death of massive stars, and are the most violent events to have occurred since the Big Bang. MSSL is investigating the relationship between the gamma-ray emission and the X-ray/optical afterglows to understand these events, as well as using gamma-ray bursts to probe the history of star formation. Our operational team performs this investigation, the team members are the most dedicated scientists willing to work and to endure these endless unscheduled tasks. Two meter long Swift Ultra Violet/Optical Telescope (UVOT) is designed and built by the MSSL. This telescope consists of four sections which include the baffle, detector, power supply and optical modular. The KT main target is nuclear energy industry.

Hinode EUV imaging spectrometer as Hinode is a joint mission with NASA, ESA and other space agencies involvement. It uses X-ray, EUV and optical instruments to study the interaction between the magnetic field and corona of the Sun. The EUV Imaging Spectrometer (EIS) was built by MSSL and its partners. The science aims of EIS include studying the coronal/wave heating, magnetic reconnection detection, solar flares, Coronal Mass Ejections (CMEs), solar atmosphere and energy transfer. The EIS Level 0 data and other higher levels dataset are available for research studies and for public outreach activities. For the KT activities which include sharing the knowledge of the high-impact and ultra-light composite materials between the Formula one racing car engineers and the spacecraft scientists. Other KT opportunities are the solar energy and magnetic field applications.

Near Infrared Spectrograph (NIRSpec) can analyze the spectrum of any objects. The results will give us the details of physical properties including temperature, mass and chemical composition. It can fingerprint the atomic and molecular states of each chemical element and physical conditions in the object. Other important research product is the NIRSpec's microshutters. It allows us to capture the spectra of more than 100 objects at once. These tiny cells are 100×200 microns each in size (i.e. comparable to human hairs thickness). Individual microshutter is operated by the magnetic field. The KT opportunities include the precise variable natural density filtered for the camera design and objects recognition.

Cassini Electron Spectrometer (ELS) instrument is a hemispherical top-hat electrostatic analyzer. This sensor is modified from the Cluster-2 spacecraft design. It measure electrons energy range. It observes the space weather such as CMEs and bow shock of magnetosphere. For example, the magnetosphere of Saturn interacts with solar wind from the Sun. The results are creating the ring of dust, Titan moon and icy satellites such as Hyperion. There are many opportunities in the MSSL Planetary Science research. These include producing spacecraft instruments, analyzing space mission data, scientific work with comets throughout the solar system, and space hardware specialty is to measure ions in space plasmas. We are leading studies of the Martian surface and atmosphere with the Mars Express mission. Suggested KT activities include high energy physics, planetary exploration and Penetrators for Moon surface.

CryoSat-2 Mission Simulation and EnviSat Radar Altimeter are launched for the precise monitoring and measuring the thickness of polar ice sheets and sea ice. The CryoSat-2 satellite has the SIRAL radar altimeter which sends a burst of pulses. The returning echoes are correlated to operate as the Synthetic Aperture Radar (SAR) mode. The frequency shift in the echoes caused by the Doppler effect is separated into strips in order to reduce noise. Then two antennas determine the path length difference by measuring the phase shift between the returning radar waves. Three star trackers are used as the reference position to increase the accuracy. The shift-on-signals are measured by the Doppler orbit and radio positioning integration by satellite. The laser tracking stations provide a very accurate measurement of the thickness of sea ice and polar region ice sheets. All these instruments can be simulated by MSSL's mission software. The KT activities include the imaging Lidar/Ladar technology, radar altimeter, SAR mode, star tracker and mission simulator.

GlobIce is an ice tracker with large database to measure and to collect global ice movement data. It includes the datasets from a number of satellites such as EnviSat, CryoSat-2, ERS-1 and ERS-2. These are the Earth observation satellites to measure and verify the impact of ice motion on the climate. GlobIce provides an accurate database and archives for climatologist and climate physicists. The major KT activities consist of climate change and global warming. Other potential collaboration opportunities include government meteorological offices, non-governmental organizations and industries such as shipping, foods production, insurance companies and tourism industry.

SOHO is the NASA and ESA joint mission. The SOHO spacecraft was built in Europe by an industrial team led by prime contractor EADS Astrium under overall management by ESA. The twelve instruments on board SOHO were provided by European and American scientists including who came from MSSL. Nine of the international instrument consortia are led by European Principal Investigators (PI's), three by PI's from the US. Large engineering teams and more than 200 co-investigators from many institutions supported the PI's in the development of the instruments and in the preparation of their operations and data analysis. It is a true multi-national collaboration. NASA was responsible for the launch and is now responsible for mission operations. Large radio dishes around the world which form NASA's Deep Space Network are used for data downlink and commanding. Mission control is based at Goddard Space Flight Center in Maryland, USA. It is a KT space programme can be further co-operation in many areas including system engineering, project management and spacecraft designs.

Cluster-2 mission includes four ESA Cluster satellites and the China Double Star. Its operation is currently monitored by MSSL and other space agencies for investigating the Earth's magnetic environment and its interaction with the solar wind in 3D. Science output from Cluster greatly advances our knowledge of space plasma physics, space weather and the Sun-Earth connection and has been the key in improving the modeling of the magnetosphere and understanding its various physical processes. This mission represents the successful example of KT and the advantage of full international collaboration. It builds the future KT in all space science studies.

ExoMars PanCam and Stereo Mapping as PanCam is an integral part of the ESA's ExoMars robotic rover. The rover will be mobile on Mars and will analyze the Martian surface with a nominal mission of 180 sols. The main scientific objectives of PanCam are to use the Wide Angle stereo Cameras (WAC) and the High Resolution Camera (HRC) to acquire images from the scenes for producing morphological information on panoramic and close views including digital terrain models, WAC stereo mapping, assessing mineral composition, measuring dust optical properties, measuring atmospheric water content, searching for hydrated minerals in rocks and soils. PanCam can operate between −70°C and +70°C and it can withstand the radiation at 4.2krad. This state of the art technique can apply to various applications including space exploration, vision aid, submersible robots and unmanned aircraft systems. It will benefit the industrial, scientific and engineering communities. KT opportunities include the future knowledge systems, Objects Recognition (OR), Software Interface Simulation (SWIS) and automation of multi-discipline applications.

Future Knowledge Systems Since the advance of microprocessors (Peatman, 1977) and Very Large Scale Integrated (VLSI) circuits (Mead, 1980) from the 1970's, many computer related science and engineering researches have grown rapidly. However, their resulting data and knowledge are fragmented and stored in various formats. They are extremely difficult to manage and correlate. These led to the vision to provide a novel approach and a unified standard to change the current data processing practices. This approach will transform the fragmented data to a generic data processing standard. Although modern computer architecture has included data processing pipelines, this development is mainly for Central Processing Unit (CPU) design. There is a need for a generic data processing approach in multi-disciplinary environments. Hence, it is timely to introduce a novel GDP. The aim of our research is to provide the GDP technique for science instruments in multi-disciplinary areas. These include high resolution three dimensional images, biological and chemical data, infrared spectrometry data, organic and molecule analysis, gas chromatography, X-ray, remote sensing, environmental data such as water, ice, optical depth, surface deposit observation and crystalline mineral composition. The high level electrical ground support equipment and electrical simulation software researches will demonstrate the novelty of GDP. The research results should also show the high quality data standard, better efficiency, maintainability, reusability and cost effective data handling capabilities.

GDP is an innovative approach for industries. It will have multi-channels input data. It will process data according to user configurable files as shown in Fig. 1. It will include Telemetry (TM) Configuration File (TCF), TM Packetized Data Configuration File (DCF) and Process Configuration File (PCF). A log file will record the data processing information for analysis and report failures. GDP will divide the output data into Level 0 raw data (L0), Level 0a packetized data (L0a), Level 1 filtered data (L1), Level 1a standalone dataset (L1a), Level 1b uncalibrated data (L1b), Level 1c calibrated data (L1c), and Level 2 compressed data.

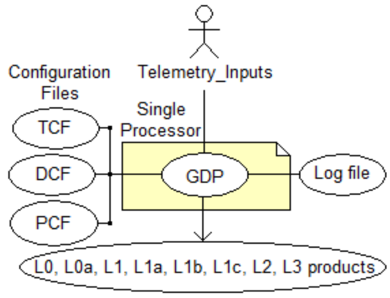

Fig. 1: Generic Data Processor

Since Dual-Core and Multi-Core CPUs are widely available, many computers are able to parallel processing data. It is time to introduce this novel high performance GDP to process multi-thread data. Fig. 2 shows the system architecture for concurrent processing. GDP will segment and local parametrize the input data. Data processing will start at the resilient two dimensional array processors. TCF will issue commands and DCF will provide data information. PCF will supply the data processing algorithms including data representation, data compression, etc. Each level will log and track the passing data. A synchronization process will safeguard the integrity of datasets.

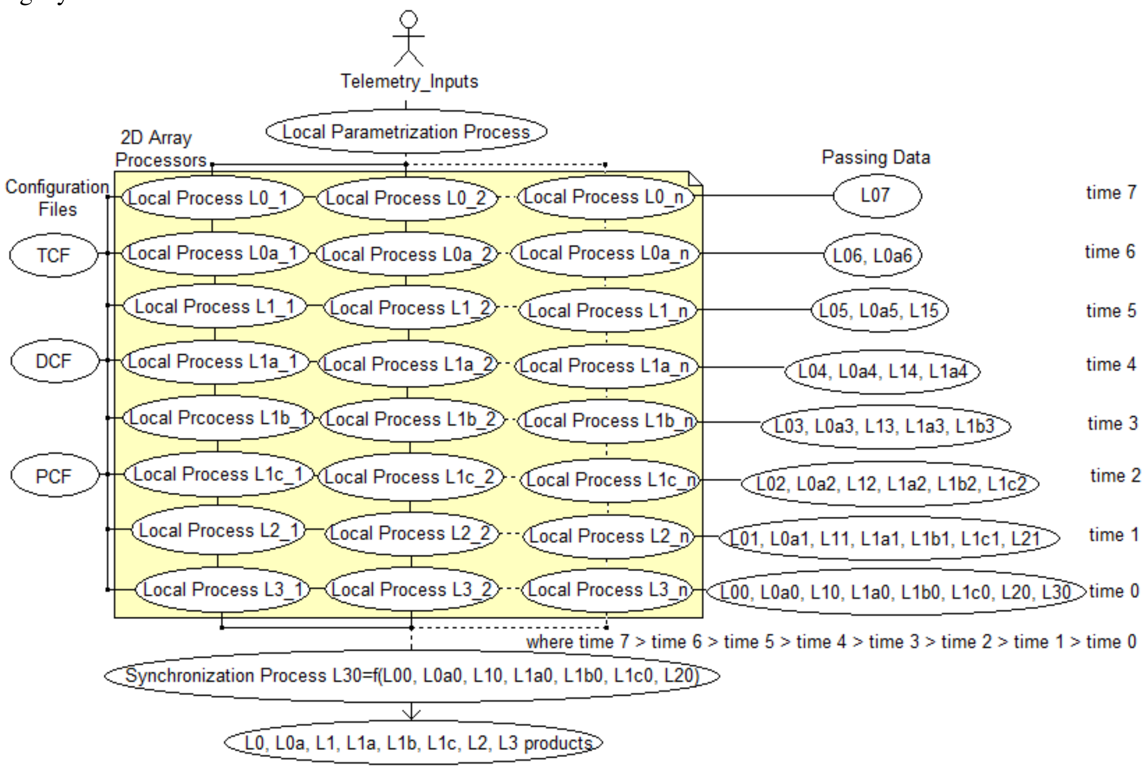

Fig. 2: High Performance GDP

Currently NASA uses the Planetary Data System (PDS) approach for data processing. The PDS uses data objects described by normal text. There is no syntax analysis of data object. It risks discovering errors only after a catastrophic failure occurred. However, the GDP approach will use the Extensible Markup Language (XML). An XML validator will check the syntax. This will increase the robustness of GDP during data processing. The ESA has endorsed this methodology.

GDP is based on an industrial research approach. It will benefit the industrial partners including Advanced Logistic Technology Engineering Centre and Thales Alenia Space. GDP will increase productivity, minimize duplicated efforts and reduce costs. We can customize the GDP algorithm into a field programmable gate array for enhancing the speed of data processing, to reduce the physical size and weight. By involving the EPSRC funded KTA programme and UCL's industrial partners, this will strengthen the future space science research collaboration amongst UCL, industrial, commercial, scientific and engineering communities.

Future Space Missions PanCam is a sophisticated and unique equipment with a HRC and two WAC mount on an optical bench which is located at the top of pan and tilt unit. Each WAC has its own filter wheel with twelve filters wavelength ranging from 440nm to 1000nm. A PanCam interface unit controlling the cameras will use SWIS as a simulator for modelling and planning the PanCam operations. They include the optical properties analysis applications, material composition assessment, terrain measurement and survey. Other functionalities include thermal control, housekeeping data logging, safe/recovery mode, failure injection and anomaly simulation. The data simulation is compliant with the ESA's GDP standard. The operational sequences will include commands, actions, tasks, activities and activity plan. SWIS will be used as an OR research tool for reducing the uncertainties of image signal noise. SWIS will provide better planning and increase the productivity for OR research. The novelty of this research is to use PanCam to acquire 2D and 3D images. These raw images can be down-sampling, sub-framing, superimposed, image processing and compression. OR will use the processed images to perform the robust curvature and torsion scale space (Yuen, 2000). Their results will be template matched using the Fast Fourier Transformation for the quick and reliable real-time response. OR can handle partial objects and occluded images. It will run under the multi-threads and multi-tasking environment at a multi-core computer. Other novelty of this research is to use HRC to increase the robustness in image acquisition, it is particularly important for the industrial and engineering applications such as hazards avoidance navigation system. Without the high resolution of the HRC it will not be possible to distinguish between a person and an inanimate structure. However, such differentiation and even identification is possible give a high resolution component in the available imaging data. This state of the art technique can apply to various applications including space exploration, vision aid, submersible robots and unmanned aircraft systems. It will benefit industrial, scientific and engineering communities. The research aspiration includes the simulation and automation of multi-discipline applications, to provide the cost-effective end products, and to allow the expansion of further research.

Conclusion

KT in space science is an important aspect of UCL. Especially, now that enterprise initiative is seen to be a vital element for KT with MSSL and its partners. Moreover, the industrial relationship between Asia Pacific and the rest of world are growing rapidly in the space science disciplinary area. In UCL, the Faculty of Mathematical and Physical Sciences Enterprise Forum comprises representatives of many major institutions. Enterprise covers the subject area of KT and consists of a variety of research and development with commercial organizations including contract research, sponsorship and consultancy. MSSL will provide the knowledge management team and support the areas including technology planning, project management, system engineering and technology translation. The details of MSSL Technology Management Group and UCL KT Partnerships can be found at http://www.mssl.ucl.ac.uk/technology/index.htm.

Literature References

Cowper , D., Smith, A., (2002), "Sharpening our axes", *IEE Engineering Management Journal*, volume 12, number 6, 261-268.

FP7, (2009), "Work Programme 2010 Cooperation Theme 9 Space", *European Commission 5893*.

Keating, D. P., (1996), "Habits of Mind for a Learning Society: Educating for Human Development", *The Handbook of Education and Human Development*, section II, part B, 21, 461-481.

Mead, C., Conway, L., (1980), *Introduction to VLSI systems*, Addison-Wesley, USA.

Peatman, J. B., (1977), *Microcomputer-based Design*, McGraw-Hill, Japan.

Williamson, M., (2010), "Supporting space spin-offs", *Engineering & Technology*, volume 5, issue 12, 14.

Yuen, P. C., Mokhtarian, F., Khalili, N., Illingworth, J., (2000), "Curvature and torsion feature extraction from free-form 3-D meshes at multiple scales", *IEE Proceedings Vision, Image and Signal Processing*, volume 147, number 5, 454-462.