ECLAT

European Cluster Assimilation Technology

A space plasma physics data resource

for the ESA Cluster Active Archive

Contents

European Cluster Assimilation Technology (ECLAT)

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1. Scientific and technical description

1.1 Concept and objectives

The European Cluster Assimilation Technology (ECLAT) programme will provide a novel and unique data base and tools for space scientists, by providing an upgrade of the European Space Agency's Cluster Active Archive (CAA). The CAA is a state-of-the-art space plasma physics data repository, which will soon contain over 10 years of magnetospheric observations from the ESA Cluster multi-spacecraft mission. Although an invaluable resource to the space plasma physics community, the multi-instrument data are difficult to mine and analyze, and lack supporting contextual data which impedes scientific progress. The ECLAT programme will ingest into the CAA supporting data from other space- and ground-based observatories, provide data mining routines, refined data products and software tools for their visualization, and develop existing European magnetospheric modelling infrastructure to provide context for the observational data. Such an open-access, on-line resource will go beyond anything currently available in the space plasma physics community.

In this respect, ECLAT will directly address the Work Programme expectation of "*developing better tools to process, access, archive and distribute data obtained from different sources such as space observatories*" and "*extending the usage of available space data (including archived data), and promoting its transfer to educational bodies, as well as the general public".*

In addition, ECLAT will enable two new fields of research: the study of magnetospheric dynamics from a "System Level" perspective, internationally recognized as a necessary step in progressing our understanding of the near-Earth space plasma environment, and developing a preparatory framework within which magnetospheric data are combined with physics-based modelling, a technique known as "reanalysis" in fields such as meteorology; in this regard ECLAT directly addresses the Work Programme expectation of "*selecting the most innovative and challenging objectives in emerging scientific fields"*.

The Earth's magnetosphere is the best observed space plasma environment in the universe, providing a wealth of information on fundamental plasma phenomena, planetary magnetospheric structure and behaviour, the environmental impact of the Sun-Earth connection, and the operational environment for space-based technology. However, the sheer volume of data available, the wide variety of observational methods, measurement types, and data formats – in situ measurements, remote-sensing observations, modelling results, on micro-, meso-, and global scales – means that fully exploiting this incredible resource is extremely difficult. At present the burden of retrieving, reading, assimilating, and visualizing these disparate datasets rests on individual scientists, placing a large overhead on any research activity, and slowing or even halting scientific progress. We propose ECLAT as a means of collecting together and assimilating existing micro-, meso- and global scale datasets, and providing tools for mining, visualizing and exploiting these datasets within a coherent framework, removing this burden from the scientist, allowing exploitation of the data to its full potential through sole concentration on the scientific content of the data.

ECLAT builds upon existing European infrastructure, the on-line repository of magnetospheric data compiled from the ESA Cluster spacecraft mission, known as the Cluster Active Archive or CAA[1] (Perry et al., 2006; Laakso et al., 2009), developed over the last 6 years at a cost of EUR 16M. The CAA was developed from a realization that previous spacecraft data sets had become unusable within a short period of the end of the mission. ESA, under the guidance of its then-head of Solar System Missions (Prof. Hermann Opgenoorth, a member of the proposing team of ECLAT), undertook to calibrate, validate, and archive the Cluster mission data and make it freely available to the wider space physics community, to prolong the lifetime of the science beyond the lifetime of the mission.

The Cluster mission (Escoubet et al., 2001) was launched in 2000, comprising four spacecraft that to this day orbit the Earth in a tetrahedral formation, sampling all regions of the near-Earth magnetosphere with their identical payloads of 11 scientific instruments. Four spacecraft are required to provide a 3D picture of the electric, magnetic and plasma environment in which the spacecraft are immersed. However, despite the unprecedented detail of this 3D image of the spacecraft locality, within the extensive region of space occupied by the magnetosphere the Cluster observations represent but a "locally-distributed point-measurement". Without a context within which to understand the observations, disparate magnetospheric measurements can be likened to the blind men and the elephant. Although the CAA contains 50 TBytes of magnetospheric observations of great scientific value, it represents an formidably complex micro-scale data set of a vast, poorly-sampled, complex, structured and dynamic system.

The CAA has constantly developed over its lifetime, mainly through international collaboration between the Cluster PIs themselves and other members of the international scientific community, bringing in aspects of coordination with other spacecraft, ground-based instrumentation, and global or regional models. In addition, an important cross-calibration activity between instruments was initiated. Such progress was reviewed at regular meetings of an external review board (of which two of the ECLAT team – Dr. Steve Milan and Dr. Rumi Nakamura – are members). Indeed, and many of the changes implemented in the CAA were at the recommendation of this review board. While the review board has constantly steered the development of the CAA, concepts similar to those presented in the current proposal have always been outside the resources available to the CAA. For instance, from the start of the Cluster mission it was realized that the context that could be provided by global scale measurements from ground-based observatories was of paramount importance. A Cluster PI role overseeing the inter-comparison of spacecraft and ground data was formed, the chair of the Cluster and Double Star Ground-based Working Group (a post previously and currently held by two – Prof. Hermann Opgenoorth and Dr. Steve Milan – of the proposing team of ECLAT), but unfortunately provision of this data within the CAA was never made, partially due to a lack of funds, but also because ESA had no coherent way to acquire and organize the data. ECLAT will fill this gap by ingesting meso-scale and global-scale ground-based data sets into the CAA. A letter of support from Dr. Harri Laakso, the Project Manager of the CAA, can be found at the end of this proposal.

The main aim of this proposal is to extend the useful science that can be achieved with the CAA, increase its user-friendliness, and enhance its data mining and visualization capabilities. This aim will be achieved through five inter-related and nested projects to augment the study of

[1] http://caa.estec.esa.int/

- micro-scale, *in situ* Cluster observations;
- meso-scale coordinated space- and ground-based observations;
- global scale and system level studies of magnetospheric behaviour;
- large-scale physics-based modelling of magnetospheric behaviour;
- “reanalysis” and assimilation of model and observations.

Each of these five themes will involve the reduction of a complex data set into a form suitable for ingestion into the CAA. This upgraded data base will facilitate detailed analysis of specific intervals of data. It will also allow comprehensive statistical investigations of magnetosphere-ionosphere coupling phenomena, which is a significant advancement from today’s situation where conclusions are often derived from individual case studies. In this context it is important to note that conducting statistical analyses which utilize multi-point space based observations and ground-based networks together is not a straight-forward task. The task becomes easier to handle if instead of a huge number of individual data records one can analyze a set of a few physically meaningful data products. This will be an ethos of ECLAT.

An emerging area of research in the field of space plasma physics is the study of the magnetosphere from a “System Level” perspective. System Level Science (SLS) is a new but established methodology in many areas of research, including biology and epidemiology, in which a holistic approach is taken to understanding the dynamics of complex systems. There is a recognition that such an approach is necessary for progress in magnetospheric physics, as evidenced by the “System Level Science” working group recently convened by the International Space Science Institute in Bern, of which three ECLAT proposers (Prof. Mark Lester, Dr. Steve Milan, and Dr. Minna Palmroth) are members, and a session devoted to SLS at the Fall 2009 Meeting of the American Geophysical Union. A key aim of ECLAT is to facilitate SLS studies by providing coordinated access to a variety of system level magnetospheric diagnostics.

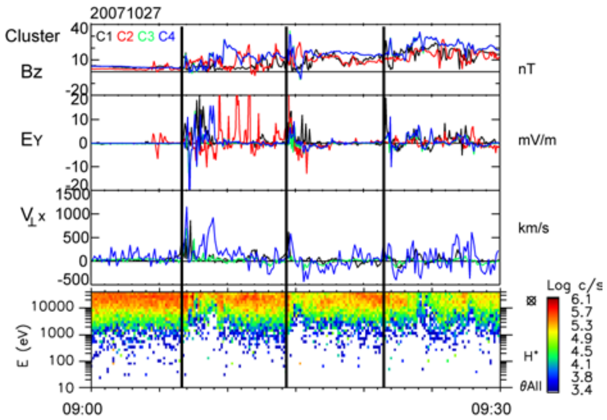
The five themes of ECLAT are described below.

1.1.1 Micro-scale, *in situ* fundamental plasma physics

The Earth’s magnetosphere is an ideal place for studying natural plasma processes in detail by using high-time resolution *in situ* measurements. Cluster four-spacecraft measurement provides for the first time 3D spatial profiles of magnetospheric processes. The Cluster Active Archive holds an extensive and complicated data set that is difficult to analyze without prior knowledge of the magnetospheric region that the spacecraft are in and the type of behaviour that is being observed. The project will develop a comprehensive list of plasma boundaries and regions from the night side magnetosphere using CAA data from all available periods (2001-2009) as input to enable effective usage of Cluster data by a wider scientific community including modelling, ground-based/ionospheric research community as well as for supporting instrument calibration activities.

The boundary/regions to be identified are those where major energy conversion/transport processes take place and which are important regions for system level science, such as the magnetotail current sheet, the plasma sheet, and the lobe/plasma sheet boundary. In addition to the list of the intervals, representative parameters such as spatial/temporal scales, orientation, and intensities will be provided as data products to be used for selection of coordinated research. A complementary project of boundary identification is planned to be realized by a separate project (sponsored by ESA) for determining the location of dayside magneospheric boundaries and the location of the magnetotail neutral sheet. Combining the product from ECLAT and those from the ESA project, a comprehensive plasma boundary data base is expected to be constructed by covering most of the key boundaries in the magnetosphere.

In addition to boundary identifications, major magnetospheric events will be identified within the CAA data using the multi-point multi-instrument data from Cluster observations (Figure 1.1) to produce an event time-line for the duration of the Cluster mission. The science events to be identified are universal processes in space plasmas, such as magnetic reconnection, plasma jets, plasma wave events, which have application also to solar physics, planetary physics and to astrophysics. In addition to the event time list, event catalogues containing representative parameters from multi-point observations and graphics showing the temporal/spatial evolution of the events will be provided.



The region, boundary identification, and event catalogues will be ingested into the CAA to allow public access to the product. These lists will enable magnetotail events to be investigated individually or on a statistical basis, in conjunction with other data sets. Furthermore, the developed tools for finding the events as well as the visualization tools will be ingested into the CAA for public use.

Figure 1.1. Example of a Cluster multi-spacecraft multi-instrument observation.

1.1.2 Meso-scale ionospheric observations for coordinated space- and ground-based studies of magnetosphere-ionosphere coupling

The Magnetometers – Ionospheric Radars - Allsky Cameras Large Experiment (MIRACLE[2]) is a two-dimensional ground-based instrument network situated in Northern Scandinavia (Figure 1.2). The network is maintained and operated as international collaboration under the leadership of the Finnish Meteorological Institute (FMI). The MIRACLE network was designed in the late 1990s specifically to support the Cluster mission. The field-of-view of the network and the spatial distribution of its stations is ideal for investigations of mesoscale (10-1000 km) electrodynamics in magnetosphere-ionosphere coupling phenomena. The MIRACLE research team at FMI has developed several advanced methods to derive value-added data products from the network's observations (Amm et al., 2005 and references therein) which has given the team a prominent role in the research community maintaining the "fifth Cluster satellite" (a pseudonym for the network of ground-based data services supporting Cluster and other multi-satellite missions).

[2] http://www.space.fmi.fi/MIRACLE/

MIRACLE magnetic field data products are related to the strength and location of the ionospheric currents. Auroral electrojets and local vortices in the current patterns (Figures 1.3 and 1.4), which under certain conditions can be associated with field-aligned currents are key elements in the research of the coupled magnetosphere-ionosphere system. These data products will be produced for the duration of the Cluster mission and ingested into the CAA, together with visualization, and quick-look tools. To allow direct comparison of Cluster and ground-based data, the magnetic mapping of the spacecraft locations to the ground must determined. This mapping depends crucially on the magnetic field model employed, and can be very inaccurate . To overcome this, magnetic field mapping will be undertaken two ways: using an adaptive-mapping strategy in which an empirical field model (e.g. Tsyganenko, 1995) is modified to account for magnetospheric state; and by magnetic field tracing within the output of the GUMICS-4 MHD model (see below).

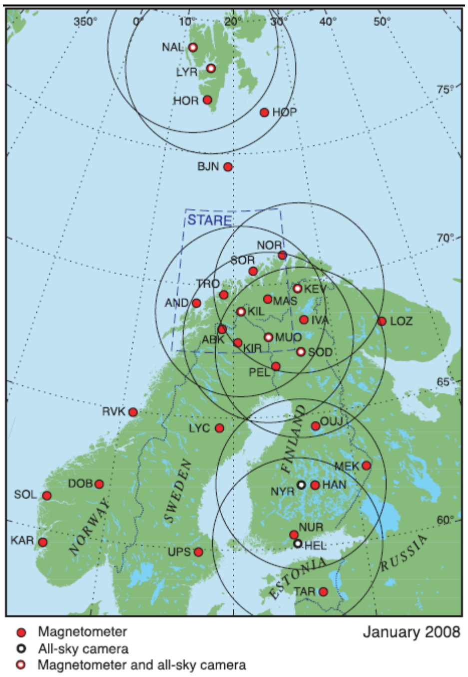


Figure 1.2. *The MIRACLE network of magnetometers and auroral cameras.*

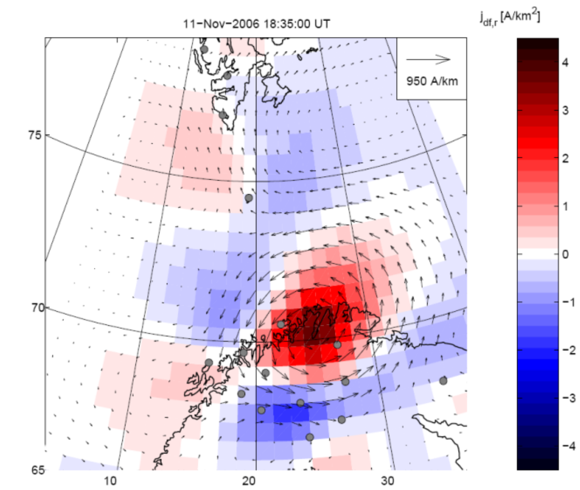


Figure 1.3. Equivalent current pattern above the MIRACLE magnetometer network on November 11 2006.

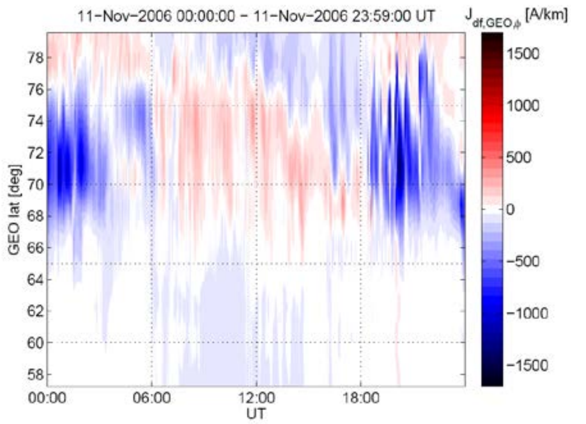


Figure 1.4. Latitude variations in the auroral electrojet intensity as monitored by the middle chain of the MIRACLE network. Negative current values correspond to westward currents.

The main difficulties of mapping between the regions include the insufficient flexibility and resolution of existing statistical models, very limited usage of adapted models, and the absence of methods allowing to control quantitatively the mapping accuracy. We expect to advance considerably the modeling capability in all three directions by (1) developing and implementing a new improved statistical model (with better parametrization and representation of current systems, taking into account the prehistory of the event and based upon a considerably increased data set; what will become the Tsyganenko 2011 model), (2) extending the adaptive modeling using a new approach (Kubyshkina et al., 2009), and (3) by implementing a new method of mapping accuracy control by using the regularly available energetic particle observations of isotropy boundaries made by NOAA-Polar spacecraft (e.g., Sergeev et al., 1993).

1.1.3 Global scale observations for system-level studies of magnetospheric dynamics and solar wind-magnetosphere-ionosphere coupling

The global state of the magnetosphere cannot be determined from in situ or meso-scale observations; for that global-scale measurements are necessary. ECLAT will ingest into the CAA global-scale measurements from the Super Dual Auroral Radar Network (SuperDARN, see Greenwald et al., 1995; Chisham et al., 2007) and the Imager for Magnetopause-to-Aurora Global Exploration (IMAGE, see Mende et al., 2000), as well as a wide variety of contextual data sets including solar wind conditions and global measures of magnetospheric activity. One of important global variables is the tail magnetic flux which can be deduced either from imager observations of polar cap area, or from observations of two spacecraft made simultaneously in the solar wind and magnetotail (e.g., Shukhtina et al., 2009). These data sets provide a window on the whole magnetosphere, with the ionosphere acting as a screen on which magnetic field line motions and particle populations can be traced at 100 km to global scale resolutions. The strengths of these data sets are amplified when they are combined to provide a picture of the global scale electrodynamics of the magnetosphere (e.g. Milan et al., 2003, 2005), and the observations will be reduced in such a manner as to make inter-comparison as straight-forward as possible. For instance, quick-look plots will show the aurora and convection superimposed, with the position of the Cluster footprint indicated, and contextual information such as the solar wind conditions, the intensity of the magnetosphere's ring current, and the auroral electrojet strengths. Such coordinated access to system level diagnostics of magnetospheric state is key to facilitating an SLS approach to magnetospheric physics.

SuperDARN comprises approximately 20 radars (a constantly growing number) in the Northern and Southern Hemispheres (Figure 1.5) which together measure the circulation of the high latitude upper atmosphere under the influence of solar wind-magnetosphere coupling. For the duration of the Cluster mission, SuperDARN will collect nearly 6M snapshots of this convection pattern. Products that will be reduced from the SuperDARN observations and ingested into the CAA will include a 2D representation of the ionospheric convection pattern, the overall convection strength, and the latitudinal extent of the convection pattern. These are key indicators of the level of geomagnetic activity, and are directly related to the physical processes occurring at the dayside magnetopause and in the magnetotail, i.e. processes that can be sampled in situ by the Cluster spacecraft.

The IMAGE satellite mission orbited the Earth providing observations of the aurorae during 2000-2005, the first half of the Cluster mission, collecting approximately 5 million images (Figure 1.6). These auroral images allow the occurrence of specific magnetospheric processes to be identified, as well as providing information on the amount of open flux in the magnetosphere, the conductivity of the ionosphere, and the overall level of geomagnetic activity. Data products related to all of these measurements will be ingested into the CAA, in a format designed to be easily assimilated with the SuperDARN data products.

These SuperDARN and IMAGE data products will be accompanied by a suite of data visualization tools that will facilitate their comparison with the meso-scale and in situ data products, and to make possible statistical surveys of magnetospheric behaviour.

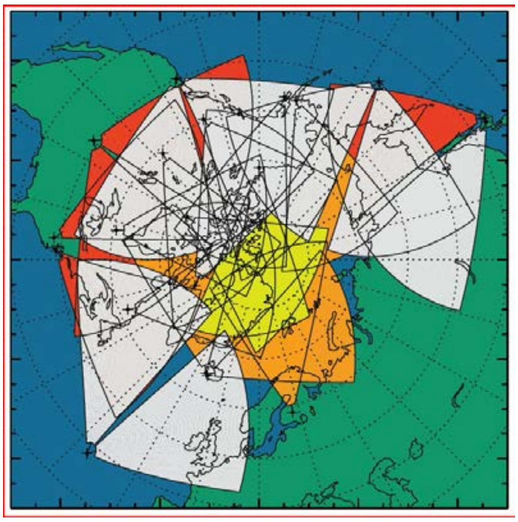


Figure 1.5. A map of the fields-of-view of the northern SuperDARN radar network.

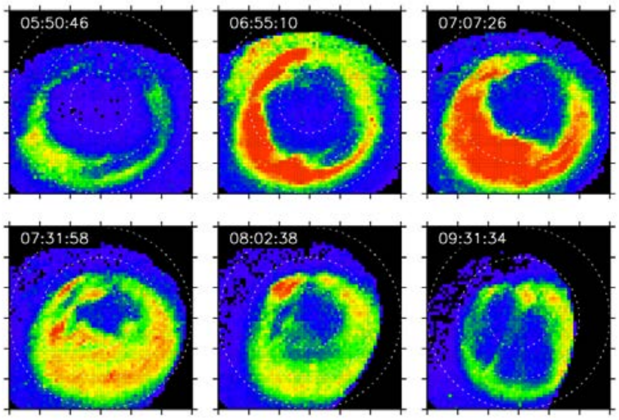


Figure 1.6. A sequence of IMAGE auroral snapshots during the course of a geomagnetic storm, covering the same geographical extent as Figure 1.5.

1.1.4 Physics-based modelling of the magnetosphere

Space missions provide *in situ* measurements from a spatially limited volume, making plasma modelling a key component of modern space research. The only European global near-space plasma simulation code, GUMICS-4 (Grand Unified Magnetosphere-Ionosphere Coupling Simulation) is the latest model in a sequence of the simulations developed at the Finnish Meteorological Institute (Janhunen, 1996; Palmroth et al., 2001). GUMICS-4 is designed specifically for solving the magnetohydrodynamic (MHD) equations of the coupled solar wind-magnetosphere-ionosphere system. The primary magnetospheric output parameters of the model are plasma density, pressure, velocity, temperature, and magnetic field in space and time. The ionospheric output parameters include the electric field, height-integrated Pedersen and Hall conductivities, ionospheric electric potential, particle precipitation power, Joule heating rate and field-aligned current density in space and time. The GUMICS-4 will be accelerated to real time operation (one day in simulation time requiring one day of computation) during 2010 in a separate project funded by the Academy of Finland.

The GUMICS simulation has been extensively tested against observational data, both in the magnetosphere as well as in the ionosphere. As the MHD equations describe the large-scale behaviour of the magnetosphere, quantities such as the location and shape of the bow shock, magnetopause, tail lobes and current sheet are reproduced realistically by the model. Quantities which depend on non-MHD physics such as overlapping plasma populations with different temperatures and more generally plasma populations characterized by different parallel and perpendicular temperatures are not reliably reproduced. For instance, the structure and dynamics of the inner magnetosphere including the ring current and the region-2 current system are less well reproduced by the model (Palmroth et al. 2003). GUMICS-4 has been applied successfully to a number of investigations dealing with solar wind energy input, its magnetospheric transfer and its ionospheric dissipation (Palmroth et al. 2003, 2004, 2005, 2006).

To overcome the sparseness of available data, and to allow the disparate data sets to be interpreted within an overall context, physics-based modelling of the magnetosphere using GUMICS-4 will be undertaken, and these modelling results made available through the FMI web-pages for direct comparison with data ingested in the CAA. These modelling results will take two forms. In the first instance, the model will be run to steady-state under a wide range of differing solar wind conditions. This will allow the expected magnetospheric structure to be parameterized by solar wind input, for direct comparison with Cluster or other data sets. This proposal is innovative in itself, but this will not reproduce the gradual evolution from one magnetospheric state to another as the solar wind changes and nor will it account for solar wind “history” that dictates magnetospheric behaviour. In the longer term, then, the model will be run continuously with real observations of the solar wind, to produce a simulation of magnetospheric state for as long a portion as possible of the Cluster mission, at a minimum a year in duration. Despite running on a supercomputer, it is expected that this simulation will take the majority of the grant period to complete. However, this will produce the first ever end-to-end simulation of its kind, providing not only context for event studies, but also large-scale statistical comparison with observational data sets. Moreover, this model output will provide detailed magnetic field tracing from the location of Cluster to the ground, supplementing the empirical tracing described in 1.1.2.

1.1.5 Assimilation and “reanalysis” of observation data and model simulation

The long-term magnetospheric simulation described in 1.1.4 is driven by observation data from the solar wind, and predicts the coupling between the solar wind and magnetosphere that dictates magnetospheric structure and dynamics. However, it is possible to go one step better to produce as accurately as possible the time evolution of the 3D state of the magnetosphere, and that is to incorporate measurements from within the magnetosphere, especially the global scale measurements of ionospheric convection and conductivity described in 1.1.3. In this way the simulation is fine-tuned to provide a holistic, synoptic 3D time-history of magnetospheric state for periods of the Cluster mission. This technique of “reanalysis”, the marriage of observational data to physics-based modelling to nudge the solution as close to reality as possible, is available in other fields, such as meteorology, but has never been attempted in a space physics context.

A complete reanalysis model requires considerable research and heavy technical development, which is impossible to be achieved during one work package of the ECLAT proposal. Hence, we provide preparatory work including preliminary investigations and testing, with a primary target to find out key information on how to develop a future reanalysis model. Nudging the magnetospheric solution means that the self-consistency and conservativity of the model are lost, indicating reductions in the code run time. On the other hand, nudging the ionosphere will not be as large a problem, while the effect will still be global within the magnetosphere.

In association with each of these themes, involving the ingestion of data into the CAA, or provision of magnetospheric simulations on the FMI web-pages, there will be a concerted development of data visualization and analysis tools. Some of these tools will be on-line, interfaced to the CAA, others will be stored at the CAA for download and operation on the user’s system. These tools will principally be developed in the common languages of IDL and MatLab, or other languages as appropriate to the task. A great advantage of the CAA is its ability to accept machine-generated data requests via ftp and equivalent internet protocols such that any of its data holdings can be automatically downloaded to a user’s institution for further analysis (Laakso et al., 2009). All data are held in a self-describing data format, making analysis of the data straightforward with appropriate tools. This will form the basis of software to mine the archive for events that meet particular criteria, including spacecraft orbit, magnetospheric region, activity type, auroral characteristics, etc. This will greatly facilitate the selection of time intervals for event-analysis, but also statistical surveys of particular phenomena.

The exact nature of the tools to be developed will be defined by the consortium partners in the early stages of the project, so cannot be described in detail here. However, we can set out our minimum requirements. These are:

Quick-look plots A comprehensive collection of quick-look plots covering all the available data sets.

Time-series plots The ability to produce highly-configurable, publication-quality time-series plots comprising multiple panels containing different data sets on the same time-axis in the same figure, including Cluster data, boundary and region information, equivalent current, ionospheric flow, auroral, system level, and modelling data. These will include simple time-series plots as well as 2D plots (see e.g. Fig. 1.4).

Spatial plots The ability to produce spatial plots of localized regions or the entire polar regions (see e.g. Figs. 1.3, 1.4, 1.5).

Footprint and magnetic field tracing plots A facility for plotting magnetic field tracing and "footprint" plots, which display the magnetic conjugacy between Cluster, the ground, and other key regions of the magnetosphere. Such plots are essential for identifying time intervals when Cluster is conjugate with different ground-based instrumentation.

In addition to these plotting tools, we will develop tools to search the archive or selected data sets for time intervals that meet user-specified search criteria. An example of a search could be to look for the phenomenon called the "cold-dense plasma sheet", in which case the user would select the search criteria a) Cluster located in the plasma sheet, b) plasma density over 1 cm^{-3}, c) low plasma temperature, d) favourable coverage of the Cluster footprint by the SuperDARN radars, e) simultaneous auroral images. Times meeting these criteria can then be output in a tabulated form, for subsequent plotting or statistical analysis.

1.2 Progress beyond the state-of-the-art

A number of magnetospheric physics data repositories and on-line modelling facilities already exist. Below we describe the general characteristics of a representative list of these resources, their strengths and weaknesses, and then outline the progress beyond these that will be made by ECLAT.

1.2.1 Present state-of-the-art

The ESA **Cluster Active Archive** (CAA) is the central repository of validated, publication-ready data from the 11 instruments on each of the four spacecraft that comprise the ESA Cluster mission. Data holdings start in 2000 and the ultimate aim is to contain all Cluster data to the end of the mission, envisaged at present for 2012. The CAA allows on-line browsing of data in the form of quick-look plots and user-defined graphical output. Data can then be downloaded to the user's home institution for further analysis with user-written, bespoke software; this download can be in the form of a user request through a web-browser or an automatic, machine-generated request through internet protocols similar to ftp. The data are stored in Cluster Exchange Format (CEF) files, a self-describing data format that allows for easy ingestion of new data types

(Laakso et al., 2009). CEF has the advantage over Common Data Format (CDF), used in many other archives, in that it is stored as "flat ASCII" and hence is human-readable. Although supporting information is included in the archive, for instance spacecraft ephemeris data, there is no other contextual data. There are currently no data mining facilities. Since going on-line in 2006, the CAA has developed an established user-base. Current statistics indicate that there are currently approximately 1000 registered users, with close to 1000 log-ins per month and downloads totalling 1000 GBytes per month.

The NASA **Coordinated Data Analysis Web**[3] (CDAWeb) has data holdings from a great many space missions from 1992 to the present day, stored in CDF format. CDAWeb allows rudimentary graphical output, but no data mining facilities are available; data must be downloaded and analyzed using bespoke software.

The NASA **Satellite Situation Center Web**[4] (SSCWeb) provides ephemeris data for a range of spacecraft missions. The SSCWeb allows magnetic field tracing from spacecraft locations to the ground, but this tracing uses empirical models that are not optimized for magnetospheric state. Rudimentary graphical output is possible, but data must be downloaded and analyzed using bespoke software.

The **Orbit Visualization Tool**[5] (OVT), developed by the Swedish Institute of Space Physics, was designed to allow viewing of the Tsyganenko empirical magnetic field model (e.g., Tsyganenko, 1995) and magnetic field tracing to the ground. It also indicates the locations of the magnetopause and the bow shock predicted from empirical models. OVT does not provide data.

The **Cluster and Double Star Ground-based Working Group**[6] web-pages, based at the University of Leicester, contain quick-look magnetic field line tracing and footprint plots of the Cluster and Double Star spacecraft, currently for the period mid 2000 to end-2007. These are a useful resource for scientists wishing to undertake space- and ground-based coordinated studies, but stops short of allowing full integration of the various data sets.

The NASA **Time History of Events and Macroscale Interactions During Substorms** (THEMIS) mission[7] comprises five spacecraft and a network of ground-based observatories (GBOs) in North America. Spacecraft observations are available on-line for quick-look graphical output, but data must be downloaded for analysis with user-written software. GBO data are also available on-line, but in a separate archive, with no method for assimilating the data products. No data-mining facilities are available.

The **Super Dual Auroral Radar Network**[8] (SuperDARN) publishes on-line quick-look plots of ionospheric convection produced by combining observations from all the radars in the Northern and Southern Hemispheres, and more user-defined plots of observations from individual radars. However, more detailed analysis requires down-loading data and user-written software. Data-mining facilities are not available.

The NASA **Community Coordinated Modeling Center**[9] (CCMC) provides on-line access to a variety of physics-based magnetospheric modelling codes, including GUMICS. Users can request model runs on a particular model for specific solar wind conditions and, once the runs are completed, can use a graphical interface

[3] http://cdaweb.gsfc.nasa.gov/
[4] http://sscweb.gsfc.nasa.gov/
[5] http://ovt.irfu.se/
[6] http://www.ion.le.ac.uk/~cluster/index.html
[7] http://themis.ssl.berkeley.edu
[8] http://superdarn.jhuapl.edu/
[9] http://ccmc.gsfc.nasa.gov/

to investigate the simulation results. Due to the constraints of computing resources and data storage, relatively short runs must be requested. There is no facility to directly compare model results with observational data.

1.2.2 Anticipated achievements of ECLAT

As can be seen above, a number of on-line data repositories are currently available to the space plasma physics community, each of which provides an invaluable resource to the space scientist. However, none of them provide the facilities necessary for a comprehensive analysis of large quantities of data, especially where the data are multi-point, multi-instrument, multi-technique, from observatories on the ground and in space. ECLAT aims to bridge the gap between these disparate data sets, to allow a fuller exploitation of the scientific measurements accumulated during the lifetime of the Cluster mission. We wish to take the best features of the currently existing on-line facilities, along with new data holdings and modelling activities, to form a research tool unparalleled in the space physics community. The anticipated achievements of ECLAT can be summarized as follows.

- ECLAT will upgrade an existing European space physics data archive, with an established user-base. The functionality and usability of the archive will be enhanced with the addition of data mining and data visualization tools. The tools will be developed to facilitate data browsing, event selection, and statistical surveys, not presently achievable with current tools.

- New data products will be ingested into the archive. Some of these additions will be value-added products that will greatly enhance the scientific use of the Cluster data already present, such as region and boundary identifications. Other additions will be new meso-scale and global scale data derived from ground-based networks of observatories, or contextual information describing the overall state of the magnetosphere. This range of data has not previously been brought together in a way that allows coordinated analysis and visualization. This will facilitate study of the magnetosphere from a "system level science" perspective, crucial for new advances in our understanding of magnetospheric behaviour.

- New tools for magnetospheric mapping (an improved statistical empirical model, adaptive magnetospheric models, methods of independent mapping accuracy estimation) will be made widely available to determine the spatial connectivity between ground and magnetospheric spacecraft observations. Together with the use of new contextual products this will be a large step to improve the quality of observation-based system-wide studies of magnetospheric dynamics.

- The CAA currently has 1000 registered users. We anticipate that up-grade of the archive to include novel research tools and the inclusion of new global scale data sets will greatly increase the number of users, and bring together researchers from two different, but complementary, research fields, *in situ* fundamental plasma physics and large-scale magnetospheric dynamics.

- The physics-based modelling aspect of ECLAT is entirely new. There is currently no library of magnetospheric state simulations for a wide variety of solar wind conditions. This will provide researchers with a 3D map of the magnetosphere, including information on the magnetic field, plasma density, pressure, temperature, and velocity at each point, and ensemble measurements such as the intensity of the ionospheric currents and strength of convection, a contextual envelope within which to interpret their observations. ECLAT will provide a minimum of one-year's simulation, especially tailored to aid the interpretation of the Cluster and allied data sets. Beyond merely contextual information, this will provide an unparalleled opportunity to test the validity of model predictions against observables.

- To our knowledge the development of "reanalysis" technology whereby observations are assimilated into the solution of an MHD magnetospheric model is unique in the field of space physics. While we do not attempt a full reanalysis model, even initial testing of such technology within the space physics context will revolutionize the field of data assimilation, field line tracing, footprint mapping, and indeed modelling itself.

- As an integral component of the delivery of ECLAT, the participants will hold a regular series of workshops and exchange visits to coordinate development activities. It is anticipated that research and scientific output by the participants will be a natural by-product of these collaborations. The new data sets acquired and the software tools developed for ECLAT will allow discoveries at the cutting-edge of current solar wind-magnetosphere-ionosphere research, and all such opportunities for progress in this field will be exploited by the participants.

- Opportunities will be sought to disseminate space- and project-related information to the non-scientific public.

1.3 Methodology and work plan

1.3.1 Overall strategy of the work plan

The work conducted in ECLAT can be divided into two phases. The first part will consist of the construction of the necessary tools, data mining and subsequent refinement of the tools, and the initial modelling phase (164 person months), while the second part consists of validation of the techniques and tools, including through scientific work (92 person months). This approximate division is visible in Figure 1.7 which shows some of the main work-flows within ECLAT. For clarity, this diagram cannot depict the whole fabric of information paths and shared responsibilities among the consortium. The description below and the actual WP-descriptions give more information about these issues.

During the first phase of the project the partners will concentrate on their dedicated tasks in mining the various data archives and developing the software for massive data product generation. The supporting assets, validated mapping tools and simulation runs will also be prepared during this first phase of the project. The work in different WPs will be conducted as a tight collaboration among various sub-sets of the consortia members which will ensure seamless communication among the project partners (in addition to the official communication in progress meetings). As described in more detail in section 2.1.3, there will be a series of 6-monthly progress and planning meetings (PMs) which will initially define the exact nature of the work to be undertaken, and will then assess the progress of the project and in particular determine whether the data formats and analysis are "fit for purpose". At key meetings, including the first PM, an external Advisory Panel (see section 2.1.1) will be invited to offer experience and expertise. Most of the data refining work will be finalized by the fifth project meeting (PM5, T0+18) although the work for some of the visualization tools and contextual data products will continue until the end of the project. PMs 3 and 5 will be major reviews, including the presence of the external Advisory Panel providing a robust assessment of the architecture, data holdings, and tools, and which will form a feedback loop into the on-going development process. This feedback loop will continue through the science and validation workshops (SWs – see below and section 2.1.3) which comprise WP600. Lessons learnt regarding the utility of the tools in these SWs will be used to further refine their design.

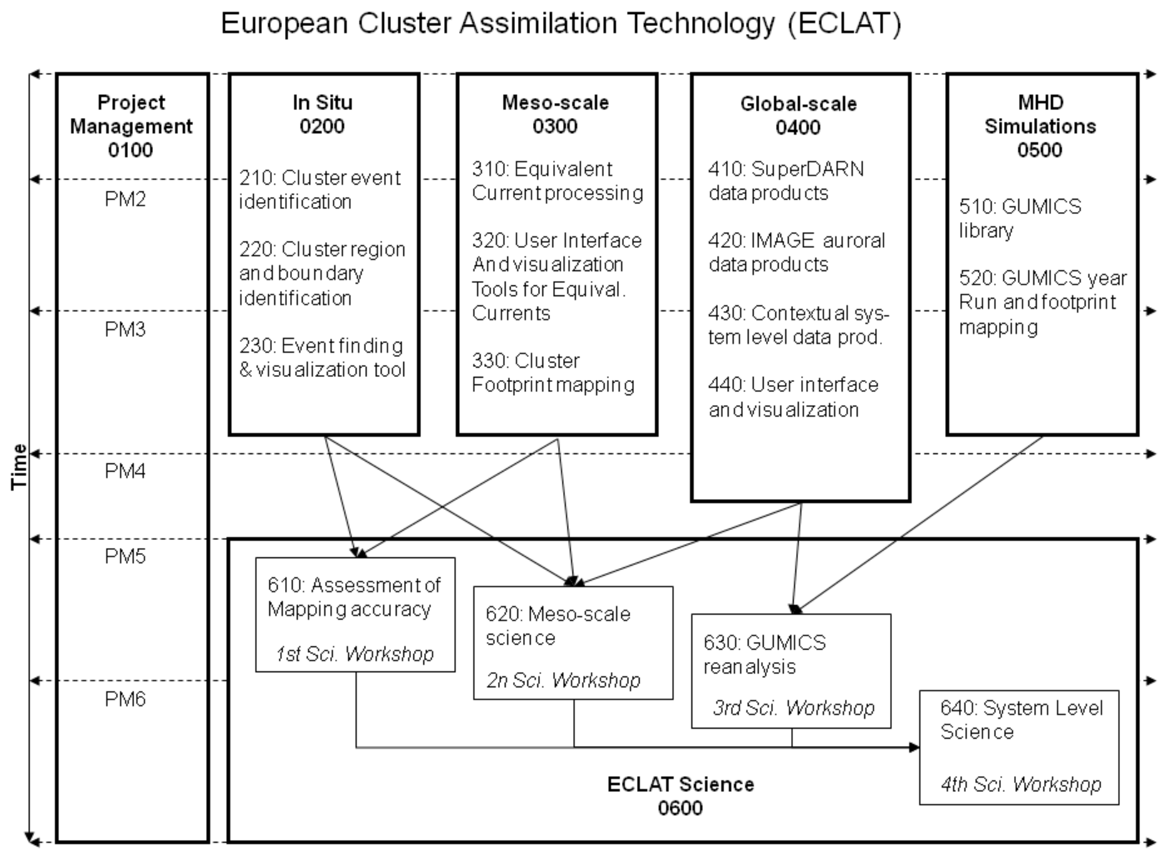


Figure 1.7. A diagram indicating the work-flow within ECLAT.

The validation and scientific work of ECLAT will gradually start during the second phase of the project. Reliable information about the error bars in magnetosphere-ionosphere mapping will be a crucial factor in the usability of the upgraded CAA services. Consequently, the validation work will begin with a comprehensive evaluation of the footprint information to be presented in the CAA (WP610). SPSU and IRF will conduct this study whose outcomes will be a list of error estimates for a representative sub-set of the given mapping results and a “guide-book” for the service users to avoid the most serious pitfalls which erroneous mapping can cause in combined satellite and ground-based data analysis. The next step in the evaluation work will be an assessment of the joint usage of the newly developed *in situ*, meso-scale and global-scale data products (WP620). The ECLAT consortium will conduct first attempts in statistical analysis of the refined geospace information. The goal is to search for new interdependences in the appearance of magnetospheric boundaries and events and ionospheric current and convection patterns. In parallel to this initiative some preparatory work for a new reanalysis model to describe the solar-terrestrial plasma environment will be conducted by FMI, ULEIC and IRF (WP630). The final WP (640) will serve as a bridge towards the new System Level Science approach in future research. From the basis of the output from the other WPs as well as experience gathered in their processing the ECLAT consortium will illustrate the power of the combined data sets in a number of example studies.

During the second phase of the project ECLAT will arrange four science and validation workshops which will be participated by representatives from all consortium partner institutes and by a number of invited external experts. For each topic in WP600 there will be a dedicated workshop. IRF will carry the main responsibility in the arrangements of these workshops and the plan is to arrange also a dedicated ECLAT session in some international scientific conference (e.g. EGU general Assembly 2012). These gatherings will serve as a platform for educating an active seed community with versatile capabilities in harvesting the upgraded CAA. The seed community will have a key role in catalyzing the wider adoption of the new services among the CAA user community.

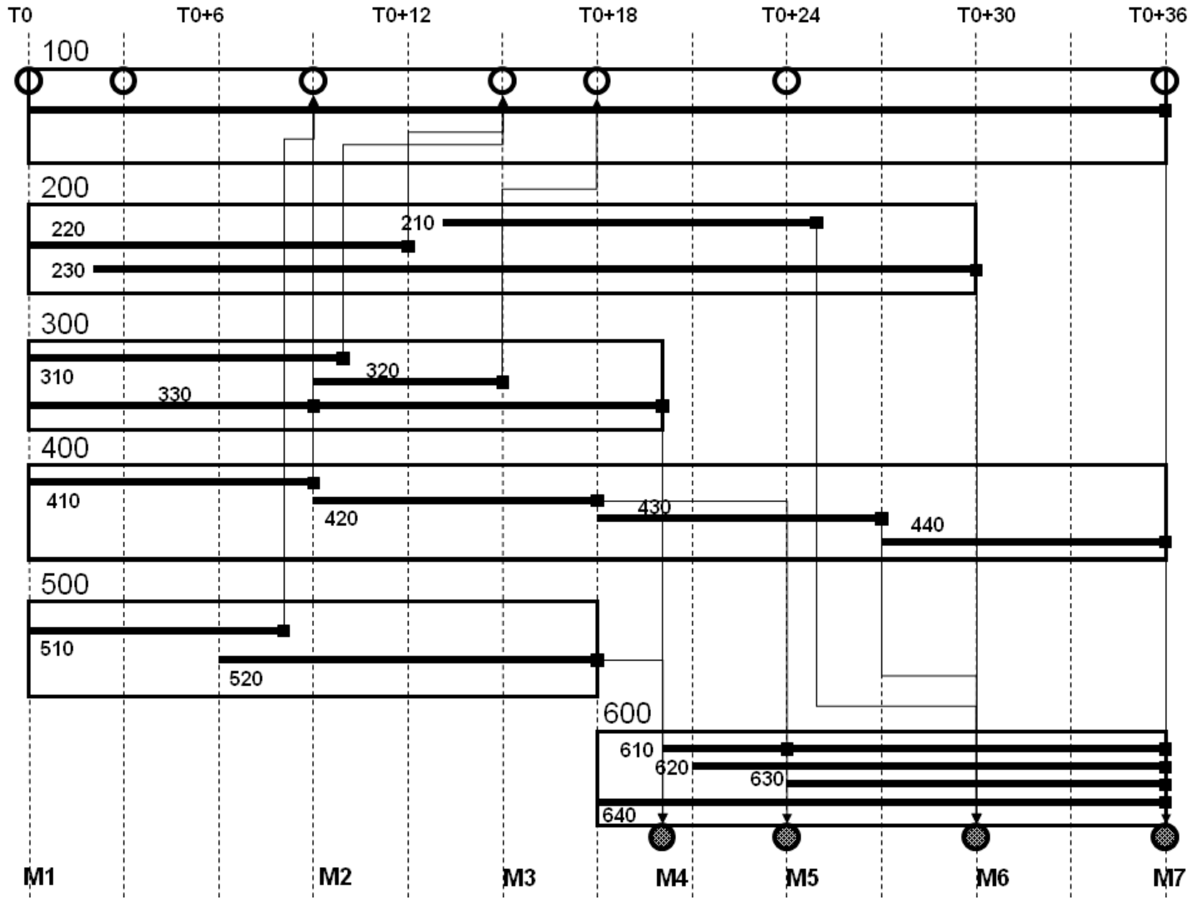


Figure 1.8. A Gantt chart indicating the durations of work packages and sub-elements of the WPs. Open circles indicate a proposed timing of progress and planning meetings (PMs) and filled circles a proposed timing of science and verification workshops (SWs) – see the management plan for details.

1.3.2 Detailed work package descriptions

In this section we provide a breakdown of the programme into work packages. Please refer to WT1 for the list of work pages, WT2 for the list of deliverables, WT3 for the detailed work package descriptions, and WT4 for the list of milestones.

The main work packages are numbered 0100, 0200, etc.; for clarity, some work packages are divided into sub-sections numbered 0210, 0220, etc. Figure 1.8 is a Gantt chart indicating the duration of the various work packages and their sub-elements.

Here follow the detailed description of the work-packages indicated in Figures 1.7 and 1.8. More detailed descriptions of the work packages, deliverables and milestones can be found in WT1, WT2, WT3, and WT4.

Work package 0100: This work package, lead by ULEIC, represents the overall management of the project (WP0100).

Work packages 0200, 0210, 0220, and 0230: OEAW will lead the activities in the mining work of Cluster data (WP200). As result of this work, future users of the CAA will have systematic information about the magnetospheric regimes which the satellites have surveyed at each time instant and about different interesting events they have recorded. Visualization tools and the search algorithms for event and boundary identification will also be available. FMI will assist OEAW in the work of identification of dayside magnetospheric boundaries since by the time of the start of WP200 beginning FMI has most probably conducted similar work in a separate ESA project.

Work packages 0300, 0310, 0320, and 0330: FMI will lead the work in WP300 which provides the CAA with information about the ionospheric current distributions in the Fennoscandian sector as a continuous record for years 2001-2009. For those periods when the Cluster footprints reside in the analysis region a tool for visualization of the current maps together with the satellite trajectories will be developed. IRF will assist FMI in the evaluation of the resulting data products. SPSU will address in WP300 the challenging task of determining reliable mapping between the magnetospheric and ionospheric observations. This work will use already existing statistical models and some adaptive models of the magnetic field for processing the CAA data and will validate the performance of these models in different geophysical conditions. IRF will support this work with their knowledge of OVT usage and development. WP300 will be run in close collaboration with WP520 where mapping between the magnetosphere and the ionosphere will be deduced from the GUMICS runs.

Work pages 0400, 0410, 0420, 0430 and 0440: ULEIC will in WP400 provide global-scale information to facilitate the interpretation of in-situ and meso-scale observations in a wider context. Output from WP400 will help also in the evaluation of the simulation runs to be conducted in WP500. WP400 will mine the massive data archives of the SuperDARN ionospheric radar network and the IMAGE satellite providing global auroral images. Both assets will provide valuable information about global energetics in the coupled solar wind magnetosphere ionosphere system. While ULEIC probes the global state with ionospheric observations, SPSU will provide supporting information by comparing in-situ data from solar wind and the magnetosphere in order to characterize the build-up of magnetic energy in the lobes of the magnetotail.

Work packages 0500, 0510, and 0520: The GUMICS simulation runs will be conducted in WP500 under the leadership of FMI. The WP will establish a general run library presenting stationary simulation results for different combinations of solar wind parameters. In addition, a one year continuous simulation run will be conducted and the resulting output will published in a dedicated FMI web-site. Quick-look data and footprint information will be ported to CAA. SPSU and IRF will assist FMI in the evaluation of the simulation output and in defining appropriate input parameter combinations for the library runs.

Work packages 0600, 0610, 0620, 0630, and 0640: These work packages relate to the science and validation workshops that will ensure the quality of the data products and software tools of ECLAT. IRF will lead this work package.

A total of 256 person-months is committed to the ECLAT project. Please refer to WT6 for a breakdown of person-months per work package within each participant.

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2. Implementation

2.1 Management structure

Here we outline the main features of the proposed management structure and procedures of ECLAT.

2.1.1 Executive board, management support team, advisory panel, and work-package leaders

The ECLAT project decision-making body will be the **executive board**, made up from representatives of the consortium partners. The **coordinator** will act as chair of the board. Decision-making by the executive board will be supported by input from an **advisory panel** of non-consortium members, also to be nominated by the executive board.

The responsibilities of the **executive board** can be summarized as follows:

- To oversee the successful running and completion of the project
- Decide on the allocation of the project's budget in accordance with the contract
- Make proposals to the parties for the review or amendment of the contract terms
- Decide on technical road-maps with regard to the project
- Decide on knowledge-management within the consortium
- Decide on measures to control and audit the functioning of the project
- Decide on project-related press releases and joint publications
- Effectively communicate decisions to the consortium as a whole

The responsibilities of the **coordinator** can be summarized as:

- Monitor compliance of the consortium partners with their obligations
- Facilitate communication within the project
- Collect, review, and submit information regarding progress and deliverables to the EC
- Prepare meetings, propose decisions, chair meetings

The **advisory panel** will comprise a number of stakeholders in the ECLAT project. Members of the advisory panel will be invited by the executive board at the kick-off meeting, and at other points throughout the project if deemed necessary. It is envisaged that these will include the Project Scientist of the Cluster mission (Dr. M. G. G. T. Taylor, ESTEC, The Netherlands), the Project Manager of the Cluster Active Archive (Dr. H. Laakso, ESTEC, The Netherlands), archiving specialists (e.g., Dr. C. Perry, RAL, UK), a representative of the modelling community, and members of the CAA user community. The responsibilities of the advisory panel will be:

- Define user requirements and needs
- Provide feedback on the progress of the ECLAT project
- Provide comments and, where appropriate, contributions to the final project report

2.1.2 Project meetings and workshops

It is planned to have 7 **progress and planning meetings** (PMs) and 4 **science and validation workshops** (SWs) during the course of the project. The PMs will in general last 2-3 days and occur at roughly 6-monthly intervals, at venues that circulate between the project partners. The first meeting PM1 will be the executive board kick-off meeting, and it is envisaged that this will be hosted by IRF at Uppsala. The exact schedule and venues of the following PMs will be decided at the kick-off meeting. The PMs will involve the executive board members, and additional representatives of the project partners as deemed necessary by the executive board of the coordinator. PMs 1, 3, and 5 will also include the advisory panel to provide input into the initial project planning and then later assessment of the progress of the project, forming a feedback loop into the on-going development of the data and tools.

As can be seen from Figure 1.6, PMs 2, 3, and 4 will occur during the main phase of the upgrade of the CAA, that is the development of data products within WPs 0200, 0300, and 0400, and their ingestion into the CAA. Prior to each of these, progress reports will be submitted by the WP leaders for consideration by the board, as indicated in the list of deliverables. As products are released to the CAA, the board will also consider user feedback gathered through the on-line feedback facilities provided by the CAA. In the case of problems in the progress of an individual WP or the project as a whole, these PMs will provide opportunities for face-to-face discussion between consortium members to find solutions for preserving the original schedule. During each meeting, details of the planned work until the next meeting will be checked as well. The meetings will be fully minuted and these minutes reported to the consortium.

PM7 will occur at the end of the project and involve final reporting of the progress of ECLAT. Although aspects of ECLAT will go on-line and be made public as the products are delivered into the CAA, PM7 will mark the official launch of ECLAT.

In the last half to one third of the project, when significant progress has been made on developing data products for ingestion to the CAA, a series of week-long **science and validation workshops** (SWs) will be convened. Where appropriate, PMs and SWs will be convened together to minimise the travel requirements of the executive board. The SWs will be attended by a wider group of the consortium representatives, and members of the advisory panel where possible. The SWs will be themed according to the nature of the science WPs 610, 620, 630, and 640 (see Figure 1.6). These SWs will perform two functions. Firstly, they will provide a crucial test-bed for the products and tools developed in ECLAT, validating the functionality of the archive. Used under “real-life” conditions, weaknesses in the data products or tools will easily be identified for correction. The spread of themes in the four SWs will ensure that all aspects of the project are tested thoroughly. Secondly, these SWs will provide the main impetus for exploitation of the upgraded CAA within the ECLAT consortium for scientific research and publication; we anticipate a large number of publications relating to scientific advances and model development to arise from the project.

2.2 Individual participants

2.2.1 University of Leicester, UK (ULEIC, http://www2.le.ac.uk/)

The University of Leicester is a medium-sized higher educational establishment, and was awarded the Times Higher Education (THE) "University of the Year Award" for 2008/9. The Department of Physics and Astronomy is world-renowned for its research in the fields of astronomy and space physics, including a long heritage in the study of the Earth's atmosphere, ionosphere, and magnetosphere, and planetary plasma environments in the Radio and Space Plasma Physics Group. The group's research was historically founded in its expertise in radio systems for the diagnosis of the Earth's ionosphere, which continues to this day in its construction, deployment, operation and exploitation of radars contributing to the international Super Dual Auroral Radar Network. In recent years, the group has become heavily involved in spacecraft missions to the Earth and other planets, including Cluster, Cassini, Rosetta, and BepiColombo. As a consequence of these activities, the RSPPG is an acknowledged world-leader in studies of coupled solar wind-magnetosphere-ionosphere systems. In the context of the Earth system this has been based on an ethos of combining multiple data sets, ground- and space-based to develop a fuller understanding of the Earth's plasma environment, and ECLAT shares this vision. Within ECLAT, the main tasks of ULEIC will be:

- Overall management of the project
- Development of data products and software tools relating to SuperDARN, IMAGE, and contextual information, for ingestion into the CAA
- Conduct research to exploit the advancements in data availability and data-mining tools arising from ECLAT

The principle ECLAT personnel from ULEIC are:

- Dr. Steve MILAN, coordinator of ECLAT. Dr. Milan is a research-active magnetospheric scientist, the PI for the Cluster Ground-based Working Group, chairman of the Cluster Active Archive Review Board, Secretary for Magnetospheres in the Solar-Terrestrial Sciences Division of the European Geosciences Union, and is a member of the ISSI "System Level Science" working group. He will be responsible for overall management of the project, the delivery of IMAGE and contextual data products and software in WP0300, and research and validation in WP0600.
- Prof. Mark LESTER. Prof. Lester is a research-active magnetospheric physicist, Executive PI of the international SuperDARN radar network, and leader of the ISSI "System Level Science" working group. He will be responsible for leading WP0300, delivering SuperDARN products and tools to the CAA and research and validation in WP0600.

2.2.2 Oesterreichische Akademie der Wissenschaften, Austria (OeAW, http://www.iwf.oeaw.ac.at.)

The Institut für Weltraumforschung (IWF, Space Research Institute) of the Österreichische Akademie der Wissenschaften (OEAW, Austrian Academy of Sciences) covers the Austrian activities in Solar System Exploration, in Near-Earth Space Plasma Physics, and in Satellite Geodesy. IWF is participating in 15 current and future Earth, Solar, and planetary missions contributing both in science as well as hardware development. The proposal team from IWF/OEAW has long successful experience in the solar-terrestrial and magnetospheric research and are involved in Cluster data analysis and include members from the Implementation Working Group of Cluster Mission. As Principal Investigator (P-I) institution of Active Space Potential Controller (ASPOC) instrument and holding Co-I status for four more instruments, IWF is maintaining the Austrian Cluster Data Center. The OEAW proposal team has so far produced more than 150 authored and co-authored publication on Cluster science. The IWF/OEAW will provide appropriate infrastructures containing offices and computing hardware necessary to complete the tasks in WP0400 and WP0600.
Within ECLAT, the main tasks of OEAW will be:

- Development of value-added Cluster data products and event finding and visualization tools, for ingestion into the CAA
- Conduct research on meso-scale and system level science arising from ECLAT

The principle ECLAT personnel from OEAW are:

- Dr. Rumi NAKAMURA, Board member of ECLAT. Dr. Nakamura is a magnetospheric scientist and leading the Magnetotail Physics Group in IWF. She is a Co-Investigator (Co-I) of three Cluster experiments and is a member of CAA Review Board. She will manage ECLAT IWF activities and responsible for development and delivery of value added data products in WP0200 and research in WP0600. Her work months (5 months) for ECLAT is 100% covered from OeAW.
- Dr. Martin VOLWERK. Dr. Volwerk is a magnetospheric scientist with extensive experience in Cluster data analysis. He is responsible for development and delivery of event finding and visualization tool in WP0200 and research in WP0600. His work months (3 months) for ECLAT is 100% covered from OeAW.
- Dr. Wolfgang BAUMJOHANN. Dr. Baumjohann is a magnetospheric/ionospheric scientist and is the director of IWF. He is Co-I of 2 Cluster instrument and has extensive experience in analyzing in situ and ground-based data. He is responsible for IWF science coordination in WP0600. His work months (2 months) for ECLAT is 100% covered from OeAW.

2.2.3 Finnish Meteorological Institute, Finland (FMI, http://www.fmi.fi)

FMI is a governmental research institute of about 500 employees providing the national weather service in Finland. FMI holds a strong knowledge in implementing EU projects as currently FMI has a coordinator role in 6 EU projects, and a co-I role in 49 other EU projects. The personnel at the FMI involved with space research is the largest in its field in Finland including about 50 employees, of whom 19 hold a PhD degree. FMI has a competitive record of building instruments, gathering and analyzing data, developing theoretical models for data interpretation, and publishing in leading peer-reviewed journals. The FMI is the only institute in Europe to possess three different types of space plasma simulation models (global MHD and hybrid, and local kinetic), and is one of the top institutes worldwide in simulating the Solar system plasma environments. In 2008, the European Research Council awarded a Starting Grant to Dr. Minna Palmroth (a member of the proposing team) to continue the unique model development at the FMI with a new Vlasov-hybrid simulation targeted as a next generation global simulation eventually replacing the currently used global MHD approach.

The northern location of Finland is optimal for operating ground-based instruments monitoring space phenomena related to aurora. FMI leads the international consortium which maintains the MIRACLE network of 30 magnetometers and several auroral cameras. FMI scientist are also active users of the EISCAT ionospheric radar system.

The key members of the FMI team are Dr. Kirsti Kauristie and Dr. Minna Palmroth. They have published close to 90 refereed papers on magnetospheric and ionospheric modelling and observations. Dr. Kauristie is head of the research group in FMI which has developed the MIRACLE data products to be used in this project. In the recently finished IPY-campaign she served as the leader of the core project 63 ("Heliosphere Impact on Geospace"). Kauristie serves also as a Topical Editor (Ionospheric Physics) in the EGU journal Annales Geophysicae and as the Chair of the EISCAT Council. The mesoscale part of the proposal will be carried out under her supervision. Dr. Minna Palmroth is an Academy Research Fellow, which is a highly competed position in Finland guaranteeing a research team leader position and funding for five years, She is also the leader of the ERC-funded Starting grant (QuESpace project) employing currently 5 doctoral students and post-docs. Dr. Palmroth is also the liaison officer for education and outreach for the Solar-Terrestrial Sciences Division in the European Geophysical Union, and the chair for Division of Astrophysics and Space Physics of the Finnish Physical Society. The modelling part of this proposal will be carried out under her supervision.

2.2.4 St. Petersburg State University, Russia (SPSU, http://www.spbu.ru/)

The Saint Petersburg State University is one of two main Russian Universities, having a status of national university, one of world known higher educational establishments. The Laboratory of Magnetospheric Physics in the Department of Earth's Physics is internationally recognised for theoretical and experimental studies of magnetospheric physics and magnetospheric dynamics and, especially, in the field of magnetospheric magnetic field modelling.

Within ECLAT, the main tasks of SPSU will be:

- Development of new improved statistical magnetospheric magnetic field models and time-varying data-adapted models; their implementation for accurate mapping between the ionosphere and magnetosphere to allow joint analyses of the ionospheric and magnetospheric-based data products ingested into CAA.

- Testing the new methods to control the mapping accuracy, their application to assess the quality of mapping when using the empirical and adapted models as well as MHD simulation models.

- Testing/application of new algorithm to calculate the tail magnetic flux based on simultaneous spacecraft observations in the tail lobes and solar wind; its ingestion into the CAA.

- Conduct collaborative research to exploit the advancements in magnetospheric modelling, especially for studies of global magnetospheric dynamics and substorm studies.

The principle ECLAT personnel from SPSU:

- Prof. Victor Sergeev. Prof. Sergeev is a research-active magnetospheric physicist, a member of scientific council of Themis project, recipient of 2008 J. Bartels medal (EGU), known by his studies of global magnetospheric dynamics (substorms and SMCs), isotropy boundaries, thin current sheets etc. He will coordinate the work at SPSU and will contribute to work packages WP0430 (Improved Cluster footpoint mapping), WP0510 (validation of GUMICS model), and collaborative studies: WP0610 (assessment of mapping accuracy), WP0620 (Meso-scale science). He will spend 2 month/year of working time for this project.

- Dr. Nikolai Tsyganenko. Dr. Tsyganenko, a senior researcher at SPSU, is famous as the author of widely-used empirical magnetospheric models T89, T96, T01 etc, being the standards in the field. He will lead the development and implementation of new improved magnetospheric model (WP0430, Improved Cluster footpoint mapping), as well as of new modules describing the magnetic field of cusp currents and of the substorm current wedge (SCW), WP0610. He will spend 1.5 month/year working time for this project.

- Dr. Marina Kubyshkina. Dr. Kubyshkina, Associate Professor and Programmer at SPSU, is one of the leaders in adaptive magnetospheric modeling, in which the spacecraft observations are assimilated to improve the magnetospheric models (Kubyshkina et al., 2009). She will lead the work on adaptive modeling (in WP0420, Improved Cluster footpoint mapping), contribute to the mapping error analyses (WP0610) and associated research. She will spend 1.5 month/year working time for this project.

- Dr. Maria Shukhtina. Dr. Shukhtina, Associate Professor and Programmer at SPSU, developed the algorithm to calculate the tail magnetic flux, based on simultaneous spacecraft observations in the lobes and in the solar wind (Shukhtina et al., 2009). She will contribute to WP0330 (contextual system-level data products) and associated research of global magnetosphere dynamics. She will spend 1.5 month/year working time for this project.

- Three young researchers (at PhD/post-doc level) working half-time will be intensively involved in the development, testing and implementation of magnetospheric models and data products, as well as in their scientific application.

2.2.5 Institutet för rymdfysik, Sweden (IRF, http://www.irf.se/)

The IRF is a governmental research organisation to particularly pursue research in space plasma and atmospheric physics. IRF (with HQ in Kiruna) consists of several sub-branches of which the IRF-Uppsala branch is the largest and scientifically most active one. Research activities at IRF in Kiruna and Uppsala concern studies of phenomena in the Earth's upper atmosphere, the ionosphere, and planetary magnetospheres. Ground-based measurements of ionospheric parameters, the geomagnetic field, optical aurora, and radio wave propagation, as well as in situ measurements with satellites are being performed. Both branches have a close collaboration and a long experience from experiments in space and on ground, spanning from the Swedish national missions Viking and Freja, over ESA's Cluster mission to interplanetary missions like Mars-Express, Venus-Express, Rosetta and Bepi Colombo. In particular, the Uppsala group has been internationally recognized for its effort in the coordination of ground-based measurements for the benefit of space missions.

Within ECLAT, the main tasks of IRF-Uppsala will be:

- Assistance in the overall management of the project
- Scientific advice to the Gumics run(s), subsequent verification of such data before ingestion into the CAA
- Verification of footprint mapping results through comparisons with other mapping methods and scientific data analysis, comparing model results to case study reality
- Conduct research on meso- and global scale to demonstrate the advancements in data availability and data-mining tools arising from ECLAT
- Supervision of data injection into and performance assessment of the improved CAA
- Organisation of scientific workshops

The principle ECLAT personnel from IRF-Uppsala are:

Prof. Hermann Opgenoorth, who has recently returned to his chair in Uppsala and is now again a research-active magnetospheric physicist. Over the last 6 years he has been Head of the Solar System Missions Division at ESTEC/ESA in Noordwijk, and as such he has been ESA Mission Manager for a.o. the Cluster mission, with overall responsibility for the initial implementation and further development of the Cluster Active Archive. Before joining ESA he has been the "ground-based coordination PI" of the Cluster mission since 1991, and before that he was responsible for similar activities between the extended Scandinavian networks of ground-based instruments (including EISCAT) and the Swedish national missions Viking and Freja. He will be responsible for leading WP0600 - CAA science - and will be supervising the data ingestion into and performance assessment of the upgraded CAA.

3. Impact

3.1 Expected impacts listed in the work programme

The expected impacts of ECLAT have already been discussed in some detail in section 1.2. Here, the expected impacts identified in the work programme are reproduced below in italics, and the contribution that ECLAT will make is then indicated below.

- *Projects are expected to add value to space missions and earth based observations by significantly contributing to the effective exploitation of collected data. They are expected to enable space researchers to take full advantage of the potential value of data sets.*

The aim of ECLAT is to gather together a range of complementary magnetospheric and ionospheric data sets into a single archive, such that subsequent analysis and interpretation of the data is greatly facilitated. These data sets include the full Cluster spacecraft mission data, 11 instruments on 4 spacecraft, together with meso-scale and global scale measurements of magnetospheric state and activity from a variety of ground- and space-based observatories. Without this combination of data, the Cluster data cannot be properly interpreted. This requires a European approach because no one country has access to all the data sets and expertise necessary to implement the ECLAT programme.

Some of the data sets that will be included in ECLAT will never before have been accessible to the community in an easy-to-use format; their provision will make entirely new studies possible. Some of these data sets will include high-level “event selection” products which will greatly facilitate the analysis of the data by allowing easy identification of intervals for study. These will be accompanied by new data-mining tools that will allow users to search for particular combinations of phenomena within the data archive. Using these tools, statistical analyses of the data will be possible, removing the reliance on “case studies”.

The burden of collecting together the data from a variety of on-line archives or the original instrument teams, reading the data and developing software tools to plot and analyse the data, usually falls on the scientist. This can be a very time-consuming and labour-intensive exercise, distracting from the interpretation of the data. The provision of such analysis and visualization tools within ECLAT, as well as the archived data, will remove this burden from the end user.

The inclusion of physics-based modelling of the magnetosphere together with the data promises to greatly facilitate interpretation of spacecraft and ground measurements by providing essential context for the observations. The proposed development of a magnetospheric “reanalysis” – assimilation of MHD model and data – is unique within the field of space plasma physics, which has the potential to revolutionize the study of the near-Earth environment.

- *Projects are expected to contribute to the much needed coordination of the exploitation of existing and future data collection, and thereby enhancing the possibility to base research on datasets providing comprehensive or full coverage, while at the same time addressing the potential need for further analysis of existing datasets. It is also expected that the projects will facilitate access to and appropriate use of data for those scientists who are not part of the team having obtained it.*

The aim of ECLAT is to coordinate access to a wide variety of existing data products – selected to give as broad a picture of magnetospheric dynamics as possible – products that are traditionally difficult to assimilate, compare, and analyze. A fuller understanding of the magnetospheric environment requires novel approaches to data retrieval, visualization, and event selection, all of which will be delivered by ECLAT. These data products will be available in formats that make them easy to use by all scientists, irrespective of background. In addition, the visualization tools that will be available will reduce the need for complicated programming on the scientists' behalf.

As well as providing a broad range of data products, ECLAT will provide a framework within which other existing, or future, datasets can be incorporated. The ultimate vision is to develop a "virtual observatory" for magnetospheric observations.

- *Furthermore, projects are expected to add value to existing activities on European and national levels, and to raise awareness of coordination and synergy efforts among stakeholders.*

The ECLAT programme is an upgrade to the European Space Agency's Cluster Active Archive (CAA). The ingestion of new data-sets and software tools into the CAA will greatly increase its use in the community. The modelling aspect of ECLAT builds upon the only existing European MHD model of the magnetosphere. The inclusion of simulation runs from this model within ECLAT will widen use of this resource within the community. The combination of modelling and observations is a synergy that has not previously been exploited.

The CAA already has a large user community. The on-line nature of the CAA makes dissemination of new information regarding the archive and its upgrade very straight-forward. In addition, on-line articles, presentations at international conferences, workshops dedicated to ECLAT, and scientific publications, will bring ECLAT to the attention of all stakeholders.