European Cooperation in the field of Scientific and Technical Research

- COST -

Brussels, 16 May 2013

COST 014/13

MEMORANDUM OF UNDERSTANDING

Subject :	Memorandum of Understanding for the implementation of a European Concerted Research Action designated as COST Action ES1305: European Network for the Radar surveillance of Animal Movement (ENRAM)

Delegations will find attached the Memorandum of Understanding for COST Action ES1305 as approved by the COST Committee of Senior Officials (CSO) at its 187th meeting on 15-16 May 2013.

MEMORANDUM OF UNDERSTANDING
For the implementation of a European Concerted Research Action designated as

COST Action ES1305
EUROPEAN NETWORK FOR THE RADAR SURVEILLANCE OF ANIMAL MOVEMENT (ENRAM)

The Parties to this Memorandum of Understanding, declaring their common intention to participate in the concerted Action referred to above and described in the technical Annex to the Memorandum, have reached the following understanding:

1. The Action will be carried out in accordance with the provisions of document COST 4154/11 "Rules and Procedures for Implementing COST Actions", or in any new document amending or replacing it, the contents of which the Parties are fully aware of.

2. The main objective of the Action is to establish the basis for a coordinated network of monitoring radars for the provision of real-time spatio-temporal information on animal movement through the air on a continental scale and for a broad range of stakeholders.

3. The economic dimension of the activities carried out under the Action has been estimated, on the basis of information available during the planning of the Action, at EUR 60 million in 2013 prices.

4. The Memorandum of Understanding will take effect on being accepted by at least five Parties.

5. The Memorandum of Understanding will remain in force for a period of 4 years, calculated from the date of the first meeting of the Management Committee, unless the duration of the Action is modified according to the provisions of Chapter IV of the document referred to in Point 1 above.

A. ABSTRACT AND KEYWORDS

Animal movement, and especially animal migration, is of great scientific and practical importance, and wide public appeal. The aerial movement of billions of organisms through Europe each spring and autumn brings enormous benefits in terms of ecosystem services, but also poses great risks through air-traffic collisions, invasions of crop pests and spread of disease. In our rapidly changing world it is vitally important that the timing, intensity and spatial distribution of these movements are monitored and the factors that drive these patterns understood. Patterns of bird, bat and especially insect migration are strongly influenced by atmospheric conditions, and the main research tool for studying large-scale aerial movements is radar. The objective of this COST Action is to foster an essential international and multi-disciplinary approach by establishing a European network of radar biologists, meteorologists and engineers, which will coordinate existing monitoring efforts and prediction of animal movement patterns, extend these to a continental scale, and improve weather radar products for meteorological applications. Researchers from across Europe and a wide range of expertise – including ecology, biogeography, ornithology, entomology, meteorology, mathematics and engineering – will join forces in the field of aeroecology to foster continental-scale remote sensing of animal migration for the first time.

Keywords: Aeroecology, Animal Migration, Atmospheric Dynamics, Global Climate Change, Weather Radars

B. BACKGROUND

B.1 General background

In order to understand macro-ecological processes, information on the movements of living organisms through the atmosphere is required. Billions of insects, birds and bats use the aerosphere above Europe for migration, dispersive movements or foraging. This enormous transport of biomass plays a key role in ecological connectivity which is a backbone for biodiversity and productivity within the ecosystem. The dynamic exchange of genetic material has profound implications for the health of the environment (e.g. the provision of essential ecosystem services), and for human societies (e.g. risks to air traffic, invasions of crop pests, and transmission of infectious diseases), and thus it is imperative that the spatio-temporal patterns of animal movements can be accurately measured, understood and ultimately predicted. These mass movements are detected by weather radar measurements and have a severe impact on the accuracy of weather radar products. Therefore

meteorologists and hydrologists need to be able to recognise and filter these biological echoes. Monitoring and studying the movement patterns of animals in the aerosphere is extremely challenging however, and thus it is an often neglected aspect of biological study. This is because migratory movements typically occur at considerable heights and over continental-scale distances. These technical difficulties can only be overcome by the utilisation of remote sensing and/or biologging technologies (e.g. satellite telemetry, radio-tracking devices and geolocators). These techniques enable the movements and flight behaviours of animals to be measured and accurately studied remotely, often at great distances from the location of the observer.

Biologging techniques can provide wonderfully fine detail on the movement pathways of tagged individuals, but typically they provide tracks for only a few individuals and set strict limits to the animals' body sizes. Therefore, they have proven less useful for tracking small animals (virtually all insects, most passerine birds and bats) and for large-scale population-level applications. By contrast, remote sensing technologies such as radar provide detailed information on the intensity, timing, altitude and spatial scale of mass movements of a broad range of taxa that move through the aerosphere. The best way to monitor the migration of flying animals at the population level is with radar, and this approach has produced many important advances in our knowledge of migration. The ideal platform to carry out standardized continent-wide monitoring of aerial movements is the existing Europe-wide network of weather radars, which in principal is already sensing these biological targets. In order to be a realistic source of information for various stakeholders several hurdles need to be overcome (see Section D).

By establishing a coordinated network of scientists with a broad range of expertise (ecology, meteorology, computational science and engineering), the Action will consolidate Europe's world-leading position in the use of radar for animal movement studies, taking this area of science a major step forward. The principal goal of the Action is to establish international and interdisciplinary collaboration needed to achieve coordinated monitoring of animal movements through the aerosphere over the European continent.

B.2 Current state of knowledge

A number of active research groups in Europe, USA, Canada, China, Japan and Australia currently use radar to study animal movements in the aerosphere, using either (i) dedicated biological radars (BRs i.e. radars built with the specific purpose of detecting bird or insect targets); or (ii) radars designed for some other purpose (e.g. meteorological and air traffic radars) but which routinely detect large quantities of biological targets (often referred to as 'radar contamination'). The use of

radar in animal movement research has produced many scientific breakthroughs, too numerous to enumerate. These new findings have revolutionised our understanding of, for example: (i) the cues that initiate and terminate migration; (ii) responses of individual flying animals to wind currents on small spatial scales; (iii) the mechanisms by which animals navigate; and (iv) responses of populations to large-scale atmospheric dynamics. But due to the long distances covered by animal migrants, and the large spatial scale of many dispersive or foraging flights, studies carried out at a small scale (i.e. typically a single research group deploying a radar at a particular location) will naturally be somewhat limited in the ability to provide the 'bigger picture'. Thus multi-national cooperation, involving the utilization and integration of multiple radars over a large geographical extent, is required to take the fledgling science of aeroecology to the next logical step – an authoritative understanding of large-scale movements within the aerosphere. Radar biology research teams have mostly worked independently, but recent multi-national collaborations using radar data have demonstrated the exciting potential of such cooperation. One such cross-border collaboration is of particular relevance to this Action; it used a dedicated ornithological radar to calibrate the bird-detection capability of several weather radars (WRs) in France, Belgium and the Netherlands. Weather radars (WRs) detect large quantities of 'clear air echo' which are caused predominantly by migrating insects and birds. Within this collaboration, algorithms for the classification and extraction of birds from WR signals have been developed and implemented on several WRs and already used to study bird movement outside the migratory season. This represents a ground-breaking advance, because if high-quality bird migration data were to become available from the entire European network of weather radars, continental-scale patterns of movement could be monitored for a group of animals for the first time anywhere in the world.

B.3 Reasons for the Action

This Action will enable a currently scattered community using diverse radar systems to establish a scientific network which enhances pan-European collaboration and fosters multidisciplinary exploitation and improvement of radar outputs and integration into animal movement research and forecast systems. The first steps have already been taken by establishing an informal group: '*the European Network for the Radar surveillance of Animal Movement*' (ENRAM). This Action will consolidate this network and invite researchers from all over Europe to participate. Sharing of expertise, data and technological advances within this community will greatly enhance the capability to monitor and predict the timing, intensity and spatial distribution of mass migrations, and perform quality control of meteorological radar products during such events.

The best tool for standardized multidisciplinary applications is provided by the Europe-wide network of weather radars (WR) coordinated by the OPERA program (Operational Program for the Exchange of Weather Radar Information) of the organisation of European National Meteorological Institutes EUMETNET. The present OPERA network provides unparalleled coverage of European airspace with 200 WRs in 31 countries and during OPERA IV (2013-17) the network will expand further. This Action is in response to interest from numerous and wide-ranging stakeholders. They wish to get a hand on this massive amount of information on animal movements, which is recorded continuously by WRs, but not accessible to them. The Action will allow coordinating and concentrating the effort of the stakeholders with their common goal to get access to the movement pattern of insects, birds and bats through the aerosphere collected by the European network of weather radars as well as BRs.

B.4 Complementarity with other research programmes

The Action expands on expertise and collaboration established during the European Space Agency Integrated Application Programme FlySafe (http://iap.esa.int/projects/transport/flysafe). During this activity, international partners from industry, academic institutes and meteorological institutes worked together to develop tools to mitigate the risk of birds to flight safety, addressing the concerns of several air forces in Europe. Currently, two complementary follow up activities to the FlySafe initiative (FlySafe2 and FlySwift) are relevant for this Action and focus on the operationalization of bird migration prediction models and bird detection algorithms for several weather radars as well as new research into the use of weather radar for migration forecasting (http://www.flysafe-birdtam.eu/index.php). The current Action is a logical follow-up and expansion of these developments and several partners and stakeholders of these activities are active researchers in the current Action.

The Action will also expand upon activities conducted within other European frameworks and will include several members of these activities. For example, ESF BIRD focused on avian migration research and provided strong foundations for the scientific component of the current Action. Furthermore the COST IC0903 Action (MOVE) on analyses of movement data brings together researchers with diverse expertise to improve methods of extracting information from large amounts of spatio-temporal data from moving objects (e.g. vehicles, people, animals, goods). Thus, the current Action will direct excellent input for MOVE and output from MOVE may facilitate information extraction and visualization of data gathered from this Action. Furthermore, valuable information will be compiled on the phenology of migratory movements which can contribute to

activities such as EUMETNET PEP (follow-up of COST Action 725) in developing a database of pan-European phenological data.
In recent years funding agencies have realized the need to invest in infrastructure for the long term storage, maintenance, integration and dissemination of ecological data. Online initiatives of relevance for the current Action include a data infrastructure explicitly designed for the storage of animal movement data and providing analysis and visualization tools, as well as an online resource which promotes collaboration in ecosystem and biodiversity research. One aim of the latter online resource is to develop virtual laboratories to facilitate research collaboration between numerous European stakeholders, a framework well suited for this Action. Furthermore, migratory birds are one of the showcases from this online resource, and this Action can provide unprecedented information for just such a showcase.
Collaboration with several of those activities will enable more efficient use of funding, time and expertise. This can strengthen the position of the current Action and increase possibilities of success.

C. OBJECTIVES AND BENEFITS

C.1 Aim

The aim of the Action is to establish the basis for a coordinated network of monitoring radars for the provision of real-time spatio-temporal information on animal movement through the air on a continental scale and for a broad range of stakeholders.

C.2 Objectives

The main objectives of the Action will be (i) to promote and supervise the implementation of a standard protocol for the extraction of animal movement data from the existing weather radar network (OPERA), (ii) establish the framework to promote coordinated monitoring of animal movements using existing radar systems, and (iii) organize distribution of information on spatio-temporal patterns of animal movements across Europe to interested stakeholders.
More specifically the Action will improve biological and meteorological target recognition capabilities by comparing movement data from biological radars (BRs) and weather radars (WRs) from existing and future research across the research groups within the Action, organize open access to the biological data tools from the WR network and data processing for research and education, and establish a basis for knowledge transfer within the new interdisciplinary research

focusing on aeroecology.

C.3 How networking within the Action will yield the objectives?

The Action will be an international network of experts from diverse disciplines. The involvement of OPERA members is essential, which is already achieved within the ENRAM Working Groups. COST networking funding will be used to coordinate administration of the Action, scientific meetings, training workshops for Early-Stage Researchers (ESR), scientific exchanges within Europe, exchanging measurement campaign data, scientific exchanges with relevant experts from non-European countries (particularly the USA) and dissemination of achievements to a broad community. This will enable Action members to achieve the following: (1) coordinate access to existing and newly collected radar data, especially from the European network of operational weather radars, as well as several dedicated biological research radars (or other equipment) in multiple countries run by members of the Action; (2) streamline algorithm application and data processing at the national level by developing documentation and running training workshops; (3) coordinate measurement campaigns and interpretation of data. National experts are typically familiar with specific processes (biological and geophysical) in their local area, but by pooling this expertise a better understanding of continental-scale processes is possible. Many experts involved in this Action already invest time in parallel research areas, but this effort lacks coordination. The Action will be progressed by investing time in coordinated activities such as meetings, scientific exchanges, workshops, etc. During this Action existing radar systems will be used, so there is no requirement to invest in new technologies; what is needed is a coordinated approach to maximise the value of the data already collected by the network of weather radars.

C.4 Potential impact of the Action

By facilitating the exchange of expert knowledge the Action will enable researchers currently working independently on similar issues to coordinate their methodological, applied or basic scientific research activities, therefore adding complementary knowledge and expertise (biological, meteorological, technological) and making faster progress than possible alone.
One of the great advantages of this Action is that it provides an added value to costly sensors already in place and already operational for meteorological tasks, putting national and international funds to even better use. The Action will result in significant benefits to the meteorological community through improved operational meteorological products, and hence better weather

forecasting, which in turn have major economic value (e.g. flood risk control, traffic management, storm warnings, flight safety, public safety, agriculture). The Action will enable studying movement on a population level at scales in space and time previously unattainable. This will result in novel research into animal movement which in turn can have a major impact on understanding ecosystem functioning, ecological connectivity between continental and intercontinental ecosystems (e.g. transmission of animal borne diseases), conservation, adaptation to global change, dispersal and movement of pests, risk mitigation for flight safety, agriculture, wind energy developments, and much more. The Action will provide a better understanding of one of the most fascinating natural phenomenon on earth, migration: this has captivated people throughout history, and still captures the hearts and minds of millions of members of the public leading to significant psychological and social benefits.

C.5 Target groups/end users

Target groups and end users that can make use of results from this Action come from diverse disciplines, several of which have common or complementary interests. Representatives of many of these stakeholders contributed to this proposal.

Ecologists

Fundamental insights will be gained about the movement of flying organisms (birds, bats and insects), significantly advancing our understanding of processes like migration, dispersal, foraging movements, identifying its causal factors, and assessing the response of organisms to global climatic and anthropogenic habitat changes.

Conservation biologists

Information on the major flyways of different organisms can be used to identify migration convergence zones and important stop-over locations, which are essential steps in the efficient conservation and management of migratory species. Currently many long-distance Palearctic migrants are in decline, and new information on movements within Europe where radar infrastructure is available is one important step towards their conservation. Furthermore, radar can also be used to monitor impact of human disturbance in existing or planned areas set aside for conservation such as the Natura2000 network and the African-Eurasian Migratory Waterbirds Agreement (AEWA) developed under the framework of the Convention on Migratory Species (CMS).

Meteorologists

Meteorologists involved in developing and implementing weather radar products and operational

forecast models will use the output from this Action to improve the quality of operational hydro-meteorological radar products and data assimilated into weather prediction models. Furthermore, meteorologists studying boundary layer dynamics and land-sea-air interactions can use the outputs of this Action for new interdisciplinary research or as indicators/sensors of meteorological phenomenon across large scales (e.g. atmospheric inversion layers identified through insect concentrations, sea breeze fronts and convective cells identified through concentrations of soaring birds).

Civil aviation

Information on bird and bat movements can be used (and is already being used in some countries) to reduce the risk of aircraft and wildlife collisions which are not only costly but can be life threatening. Better knowledge about insect movements can reduce false warnings by radar systems.

Risk assessment

This is a broad range of stakeholders either directly involved in risk assessment or in need of risk assessment for project planning. This spans fields like agriculture, epidemiology, wind energy, land use planning, infrastructure planning and design (high power lines, bridges, tall buildings). Information can be used to monitor and potentially predict spread of potential pests, carriers of disease (zoonoses), and collision risk with tall human structures.

General public & education sector:

Animal movement has fascinated humanity for millennia. Information on animal movement on a continental scale may become as accessible as weather forecasts already are. Such information can also be integrated into education programs from elementary school to graduate research programs and increase general awareness of biodiversity, connectivity and life on earth.

D. SCIENTIFIC PROGRAMME

D.1 Scientific focus

The principal goal of the Action is to put in place the infrastructure (i.e. develop and extend the embryonic European biological radar network, ‘ENRAM’) and to build the capacity to retrieve and interpret biological data collected by the Europe-wide network of weather radars, to achieve coordinated monitoring of animal movements through the aerosphere above Europe. The most significant outcome will be the ability to track movement of multiple taxa at the population level and on a continental scale for the first time.

The main research tasks are to improve detection and classification of biological targets with weather radar, conduct cross calibration experiments, integrate information from multiple sensors to

monitor aerial animal movement of multiple taxa on a continental scale, to study drivers that influence movement patterns.

The Action, will achieve the Objectives (Section C.2) through four interdependent Working Groups (WGs).

WG1 will focus on the classification and retrieval of biological information from the European network of weather radars by optimising / modifying existing bird-detection algorithms. The WG will establish a protocol for standard algorithms for the identification of insects and bats, and then promote the implementation of the algorithm(s) on operational weather radars across Europe.

WG2 will focus on the calibration and validation of the biological data produced by the implementation of classification-algorithms on the weather radar network. This will be achieved by carrying out calibration experiments involving the deployment of multiple sensors and aerial collection devices at the same time and location, and within the sensed volume of a weather radar. The information gathered by WG2 will be provided to WG1 in an iterative fashion, so that classification-algorithms can be refined, improved and ultimately implemented throughout the 4-year period. Such algorithm development work is part of the normal activity of some of the participants, but the advantages and added value from the Action will be the extension of the database enabling a wider range of meteorological conditions and migration situations, exchange of best practices and the possibility of inter-comparison of techniques so far developed independently.

The third and fourth WGs utilise the new biological data emanating from the weather radars, and already available for several radars in the Netherlands and Belgium. WG3 will improve visualisation techniques to enable more versatile representation of migration features in relation to meteorological conditions and disseminate spatio-temporal patterns of animal movement data. WG4 will review current knowledge and work out new and hitherto unanswerable research questions related to continental-scale animal migrations through the aerosphere, and define grand challenges and priorities to steer future research conducted by Action members.

D.2 Scientific work plan methods and means

The Action will achieve its scientific goals through the formation of 4 Working Groups (WG) which will last for the duration of the Action (4 years). The WGs are interdependent on each other and so there will be consistent dialogue and frequent meetings between all WGs to enable exchange of information. The WGs will coordinate the publishing of joint research results in scientific journals and at scientific and stakeholder related conferences.

WG1: Classification and Retrieval of Biological Data from European Weather Radars

WG1 will assess and evaluate biological-classification algorithms on data from the European weather radar network, with the ultimate aim of ensuring consistent high-quality spatio-temporal information on animal movement intensity in the aerosphere above the whole of Europe and improving the quality of meteorological outputs. At the first stage, data which is already collected from a few weather radars will be processed with the basic algorithm, reviewed and approved. Experts will assess output in joint meetings and determine whether specific modifications are needed for different areas in order to work towards optimised versions of the algorithm tailored to fit the specifications of individual weather radars (the 'refined bird-algorithm'). Refined bird-algorithms will then be rolled-out across the entire network. National meteorological institutes will be motivated and supported to implement the algorithm for automated and routine data processing. Later stages will focus on setting up protocols to coordinate research performed independently from the COST Action, by the single group members.
The work-plan of WG1 will include the following steps, and frequent interaction with WG2 who will provide data and knowledge essential to establish and launch the biological-classification algorithms.

- Test algorithms on several operational weather radars across Europe (at least 6 weather radars from 4 countries in the first instance).

- Discuss the analysis of existing data from a limited number of operational weather radars in detail.

- Compile an inventory of different radar operating practices across Europe (through OPERA).

- Facilitate the use of OPERA Data Information Model (ODIM) and the NEXRAD data format (for WRs in the USA) to ingest operational weather radar data, so that the algorithms can be applied to data from radars across Europe. Promote the application of the 'refined bird-algorithm' for operational use at meteorological institutes, so that these can provide the ENRAM network with these data.

- Make the current bird algorithm suitable for operation on S-band radar (needed for southern European countries).

- Coordinate the collaboration with colleagues in non-European countries.

- Organization of training workshops for both scientists and radar operators on biological retrievals from weather radars, and provision of the new biological-classification algorithms to the entire research community.

- Setting a standard protocol for consistent and quantitative continental-wide monitoring of animal movements through the European aerosphere by the network of operational weather radar networks.

WG2: Improvement of Weather Radar Data Quality and Validation of Biological-classification Algorithms

WG2 will provide data from groups currently monitoring aerial movement to 'ground-truth' (i.e. calibrate) the biological aspects of the weather radar data, and to validate the biological-classification algorithms produced in WG1. WG2 will coordinate and stimulate cross-calibrations of different dedicated biological radars and the weather radar network, with respect to their capabilities of detecting and classifying a broad range of animal taxa in the aerosphere (insects, birds and bats). This knowledge will form the basis of the evaluation of the suite of biological-classification algorithms by WG1. The work-plan of WG2 will include the following steps:

- Link research groups to conduct comparative analysis of pre-existing data from dedicated biological radars (for birds and insects), and pre-existing data from operational weather radars that is believed to represent various biological targets (birds and insects).

- Create a platform for the organization of a cross-calibration measurement campaign, involving the simultaneous deployment of multiple remote sensors within the sensed volume of an operational dual-polarisation weather radar. The remote sensors to be deployed will include as many existing systems as possible (e.g. air traffic surveillance radar, ornithological radar, entomological radar, thermal imaging equipment, LIDAR (Laser Imaging Detection And Ranging), acoustics for flight call identification, etc.).

- Assure and evaluate validation of the first roll-out of the 'refined bird-algorithm' across the weather radar network, and investigate the potential of the more advanced classification-algorithms to produce high-quality quantitative data on the complete set of potential target animals.

WG3: Visualizing Spatio-temporal Patterns of Animal Movement

WG3 will use data produced by the weather radar network to quantify spatio-temporal patterns of aerial animal movements at different scales in space and time. The following activities will be the focus of WG3:

- Evaluation of infrastructure for efficient storage and retrieval of biological information extracted from weather radars in close cooperation with OPERA.

- Fostering collaboration between computational scientists and biologists to design infrastructure for efficient visualization of biological information extracted from weather radars and the most relevant environmental factors.

- Mapping animal movement at large scales (across multiple radars).

- Evaluation of statistical modelling approaches to quantify the influence of atmospheric dynamics on animal movement (local to continental).

- Investigating the degree of spatio-temporal correlation between radar sites for different movement patterns and taxa and the causal factors underlying the large-scale patterns.

WG4: Significance and potential of Animal Movement Research

WG4 will evaluate the needs of the stakeholder communities as well as assess the applicability of recent findings in research and explore new research possibilities that will emerge from the previously unattainable data. By its very nature, the tasks of this WG are somewhat speculative at the moment, as many more ideas will surely emerge following results from other WGs. The activities of this WG will be re-evaluated by the MC during the course of the Action. Some tasks that merit consideration include the following:

- Review of existing European studies of animal movements employing (weather) radar.

- Analysis of the present and future needs of animal movement data and applications in all stakeholder communities.

- Annotated review of the existing algorithms for diagnosing and quantifying animal movements and recommendations for future extensions of them.

- Recommended practices (roadmap) at the national and pan-European (OPERA) level for optimal use of animal movement information in operational radar systems.

- New opportunities for animal movement research like,

    - The potential to estimate temporal patterns of biological productivity in different areas of Europe, based on variation in aerial biomass of locally-produced airbone organisms throughout the year.

    - Investigate the effect of spatial variation in anthropogenic light pollution on nocturnal aerial biomass and migration routes – is artificial light a hindrance or help to nocturnal migrants?

    - Look for signatures of climate change and/or land-use management in the migration routes or behaviours of a wide range of migratory taxa.

    - Identify major flyways and stop-over regions of migratory birds, with relevance to conservation biology.

E. ORGANISATION

E.1 Coordination and organisation

The Management Committee (MC) will coordinate the entire Action, and will oversee the set-up of the WGs and define their directions. The MC will consist of two delegates from the signing countries. Efficient day-to-day management will be ensured by the Steering Committee (SC), consisting of the Action Chair, the Action Vice-Chair, and the WG Leaders. Practical activities requiring cooperation amongst members will be accomplished mainly through Short-Term Scientific Missions (STSMs) which will be planned and managed by a dedicated member of the MC. The Action will involve experts from outside Europe and representatives of relevant organisations, agencies or associations such as members of the MOVE COST Action. The SC will be in charge of organizing the MC and WG meetings and the workshops. The MC will define the large strategic orientation of the Action and integrate the results of the WGs. The MC will also ensure the promotion of the Action, the dissemination of its results and structuring the interactions with all relevant stake-holders. The SC and MC will also promote and encourage the use of STSMs for learning, comparing and testing the new algorithms, disseminating best practices and inter-comparisons of instruments and procedures. WGs will have a Leader and a Deputy Leader for ensuring proper combination of all requested expertise from meteorology to ecology through radar engineering in order to effectively perform the work. The initial Kick-off Meeting at the start of the Action will distribute the tasks among all the participants to the Action, based on a survey of the respective expertise. At this meeting, the makeup of the MC (including nomination of the Action Chair and Vice-chair), and the identification of the Leaders and Deputy Leaders of the WGs, will be agreed.

The MC will meet biannually to review progress, and to discuss how to achieve the next milestones and deliverables by each of the 4 WGs. The MC will coordinate research carried out and financed by the participating countries. If more frequent discussion is required, then additional MC discussions will be arranged via video conferencing. Experts from outside the Action, including from the USA and Far East, will be invited to attend the MC meetings (or at least part of them) when they can have an important input to a particular topic. WGs will also hold biannual meetings (see below), and where applicable these meetings will be held alongside the MC meeting to promote the efficient flow of information. The SC will meet either prior to MC meetings for preparing the topics to be decided or on an ad-hoc basis when necessary.

A dedicated website for the Action will be set up, and managed by an elected website manager who will be responsible for ensuring the rapid updating of material. The website will have a public section, open to all interested parties, which in due course will feature interactive maps of migration intensity as data becomes available. The website will also have a password-protected members-only area, for participants in the Action, where documents and data can be securely shared and stored.

This part of the website will also have a forum where questions, requests and answers will be posted and viewed by all members of the Action.

In the third year an important milestone of the Action will be an international symposium on "*Radar Observations of Animal Movement in the Aerosphere*", at which members of the Action and other invited experts will present the latest research on aerial animal movements. This symposium may take the form of a stand-alone conference, or may be integrated within a larger international ecological conference. It will provide a forum for presenting the progress of the Action to the wider community, and exchanging ideas and new scientific methodologies with experts from outside the Action. Each speaker will be invited to submit an expanded version of their talk as a scientific paper, and the MC will organise a special issue of a respected journal in which to publish these papers in one place as a deliverable for this Action (e.g. *Philosophical Transactions of the Royal Society* does special themed issues).

Smaller workshops and Training Schools for ESRs will also be arranged, predominantly focusing on data handling, interpretation, analysis and visualization. The MC will have responsibility for organising these (although, in certain cases, responsibility for specific meetings will be devolved to the most relevant WG).

The MC will also promote the use of STSMs, especially for ESRs, via which many of the advances will be realised, and where possible these exchanges of scientific staff will coincide with WG meetings and/or workshops, to maximise productivity and progress. STSMs, lasting either 1-month or 3-months, will be awarded to individuals who apply with a written proposal to dedicated members of the MC responsible for this aspect.

E.2 Working Groups

Working Group Leaders and Deputy Leaders will be elected at the Kick-off Meeting. The Leader will be an acknowledged international expert in their field, and when possible the Deputy Leader shall be an ESR; and both shall sit on the MC. Each WG will meet biannually to set milestones and review progress. All participants in the Action will belong to one (or more) WGs, and typically most members will attend the relevant annual WG meetings.

The 4 WGs are described in detail in Section D.2; while each of these WGs has clearly-defined scientific goals, they are all highly dependent on each other and will require a constant flow of information between them. This will be realised on a day-to-day basis via the private area of the Action website, while the annual MC meetings will also allow the Leaders and Deputy-Leaders of the WGs to discuss items in more detail face-to-face. At times, specific meetings may be organised

that will bring members of 2 or more WGs together if required.
The structure of the WGs will be very flexible, to allow new members joining the Action throughout the 4 years duration to join WGs that most suit them, and for existing members of the Action in different WGs to participate in specific tasks carried out within another WG.
The MC will supervise and if necessary, adapt the milestones listed below. The Milestones (M) and corresponding deliverables (D) to ensure attainment of the Action objectives are:
M1– D1: Current situation assessment in Europe relating to remote sensing of aerial animal movements (WG 4) (month 12).
M2– D2: Recommendations for future European research programmes and actions, first report (month 24), final report (D2) - (month 48).
M3-D3: Handbook for the weather radar provider on "How to implement filter algorithms in weather radar to extract biological targets" – first internal version (M3) - (month 28), final version (D3) – (month 42).
M4- D4: Handbook of "Best Practices" for data collection and analysis of biological weather radar data - first internal version (M4) - (month 28), final version (D4) - (month 42).
M5-D5: European Database on spatio-temporal distribution of birds, bats and insects: first "beta" version (M5) – (month 28), final version (D5), (month 42).
M6-D6: International symposium "*Radar Observations of Animal Movement in the Aerosphere*" inviting speakers and participants from within and outside the Action, (month 36)
M7-D7: Final report/guidelines/conclusions of the Action, draft contents, authors, schedule (month 32), final version – (month 48).
The research will be carried and financed by the participants while COST will provide the necessary coordination.

E.3 Liaison and interaction with other research programmes

The Action will interact with a similar network currently under establishment in North America as well as the MOVE Action as described in section B.4 through joint meetings. A close cooperation with people involved in the OPERA program is a necessity, and guaranteed by active OPERA members within ENRAM. Furthermore many of the Action participants are currently involved in national research programmes of relevance and thus interactions between these programmes will be facilitated. This is especially true for applied research programmes that are often funded by national agencies but can benefit from international exchange. More detail on interactions with other research programmes can be found in section B.4.

E.4 Gender balance and involvement of Early-Stage Researchers

"This COST Action will respect an appropriate gender balance in all its activities and the Management Committee will place this a standard item on all its MC agendas. The Action will also be committed to considerably involve Early-Stage Researchers. This item will also be placed as a standard item on all MC agendas".

During the election of the MC and WGs, and in the award of STSMs to individuals, appropriate care will be given to respect an equal gender balance, and to involve Early-Stage Researchers (ESRs), wherever possible.

Specific members of the MC will monitor gender balance and the development of Early-Stage Researchers and act as contact persons. Aims to establish a quota of at least 30% of female members in the Working Groups would be unrealistic as the field has been historically male dominated. However, women from participating parties will be stimulated to join the MC and act as WG Leaders or Deputy Leaders. Currently several women are involved in the informal ENRAM network: 17% are female (5 out of 29), confirming that a greater goal would be initially unrealistic. However, the Action will encourage networking between female researchers whenever possible.

ESRs will be supported according to the "COST Strategy towards increased support of Early-Stage Researchers", i.e., by supporting ESRs to act as national delegates, by offering at least 2 STSMs per year, and by offering Training Schools for capacity building. Where possible, STSMs will typically be awarded to Early-Stage Researchers as a priority. ESRs will be stimulated to take an active role in the Action by being involved in joint publications or conference contributions. ESRs will be actively stimulated by senior Action members to take advantage of STSMs who will assist in defining clear milestones and deliverables for ESRs.

TRAINING SCHOOLS: A strong effort will be made to promote the Action outside the Action partnership, especially towards ESR and female scientists, technicians, users and practitioners. A Training School will be organised by the Action addressing issues such as the processing, visualization and analysis of aerial animal movement data. The Training School(s) will also aim at achieving capacity building goals for newcomer countries and/or institutions (see for example a previous summer course on the topic of 'Animal Movement Analysis' http://horizon.science.uva.nl/scge2012-wiki/doku.php?id=og1#summer_course_animal_movement_analysis.)

F. TIMETABLE

The duration of the Action will be 4 years. MC meetings will take place biannually, the first of them within 6 months of the initial Kick-off meeting, and they will be generally organised back to back with WG meetings to allow integration of the WGs' activity by the MC, findings of the MC to be disseminated and acted upon. There will be a Training School in year 3 at which internationally-renowned experts will lead discussion and practical sessions, and to which all interested parties will be welcome to attend. The international symposium described in section E.1 will be held in year 3. Relative times for specific deliverables and milestones are provided in section E.1.

	Year 1				**Year 2**				**Year 3**				**Year 4**			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Kick-off Meeting	X															
MC Meetings			X		X		X		X		X		X		X	
WG Meetings			X		X		X		X		X		X		X	
Website	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Training School									X							
International Symposium												X				
Calibration Experiment			X			X	X									
Implement Algorithms			X	X			X	X	X	X	X	X	X	X	X	X
Analyse & visualize Outputs				X	X				X	X	X	X	X	X	X	X
Publications							X	X			X	X	X	X	X	X
External Presentations				X				X				X				X

Reporting								X				X				X

G. ECONOMIC DIMENSION

The following COST countries have actively participated in the preparation of the Action or otherwise indicated their interest: BE, CH, DE, DK, ES, FI, FR, IL, IT, NL, NO, PL, RO, SE, UK. On the basis of national estimates, the economic dimension of the activities to be carried out under the Action has been estimated at 60 Million € for the total duration of the Action. This estimate is valid under the assumption that all the countries mentioned above but no other countries will participate in the Action. Any departure from this will change the total cost accordingly.

H. DISSEMINATION PLAN

H.1 Who?

In the first instance the primary audience for results from this Action is the biological community studying animal movement for a range of research questions, as well as the meteorological community developing and using weather radar projects. This includes a range of research institutes and national meteorological institutes. Meteorological institutes will be able to implement algorithms to extract biological targets from their radar signals and thereby also improve their meteorological products.

A wider range of stakeholders that can use information on animal movement for risk assessment or mitigation include: aviation (flight safety collision risk between birds, bats and aircraft); regional governments for land use planning; the renewable energy industry (collision risk with wind turbines); nature conservation organizations (national and international, for example BirdLife International, the Convention for Migratory Species); organizations interested in potential transmitters of disease or movement of pests for food and human safety (for example the FAO, national health agencies, national departments of agriculture, private-sector firms). Similarly, a broad range of consulting agencies can use this information to develop risk assessment and mitigation plans and proposals. Radar manufacturers and software developers can use the findings of this Action to improve their products for the ecological and meteorological community. Finally information on animal movement will be of interest to the public, for general interest purposes as well as education.

H.2 What?

For the research network, and broader public interested in following the progress of the Action, information and meeting reports will be posted on the Action website. Research results aimed especially at the scientific community will be exchanged through peer-reviewed scientific journals, in specialist and as well as multidisciplinary journals. Several software packages will be shared via web portals and software exchange infrastructure such as CRAN (The comprehensive R archive network, http://cran.r-project.org/).

Data processing and analysis tools developed during the Action and key recommendations will be disseminated through training workshops and scientific exchanges for both the biological as well as meteorological community.

Non-Action conferences and workshops will be used to disseminate results directly to the research community (scientific conferences) as well as to particular user groups and stakeholders through more applied workshops (such as workshops on renewable energy, flight safety – see for example the International Bird Strike Committee). The aim of user group and stakeholder dissemination will be to broaden the impact of the Action's work and increase awareness of the possible applications by different user communities.

Action members involved in other research networks (migration research network, OPERA, Baltrad) will increase awareness of the Action activities. The Action will also organize workshops to present and discuss results, some of which will be internal for the Action and others will be larger symposia open to the broader scientific community.

Action members will also disseminate results locally through local and national media when relevant through press releases, interviews, newspaper articles etc. Visualizations of the data will be developed for the general public and presented on a website to stimulate public awareness of Action activities.

H.3 How?

Information shared on the internet will be used to potentially expand the network during the course of the Action and identity new key participants for future endeavours. Publications in scientific journals will be used to communicate and share research results and developed algorithms with the scientific community at a high scientific standard, ensuring that the developments within the Action are at a standard acceptable and understandable by a broad scientific community. Publications will also be used to monitor our own progress within the Action and identify gaps in knowledge and areas for improvement.

Training workshops and scientific exchanges will be used to train researchers in the methods developed and implemented during this Action with an emphasis on young researchers from different countries. This will stimulate and catalyse studying animal movement and improving meteorological products across national borders.

Dissemination to a broader range of stakeholders will be used to also monitor, maintain and convey milestones and ensure that results achieved are not only of interest and use to the Action members but can be extended to a broader user group that can take advantage of our work. Meeting reports will be used to communicate results between members present and those not present at meetings, and to ensure that all members are up to date on Action activities. Meeting reports will also be used to periodically review the timeline and milestones of the Action and reassess and reschedule if needed.

Feedback received from different forms of information dissemination will be used to make improvements or adjustments to plans if needed (whether research or dissemination related) and can be used to help focus specific activities and acquire additional funding in the future.