ANNEX IV

COST

Technical Committee “TIST“

COST Action **271**

Effects of the upper atmosphere on terrestrial and Earth-space communications

FINAL EVALUATION REPORT

The first part (para. 1-8 is prepared by the TC Scientific Secretary in co-operation with the Rapporteur and the MC Chair on the basis of the last progress report of the Action).
The second part (para. 9) is prepared by the "ad hoc" Evaluation Panelestablished by the Technical Committee and edited by the Rapporteur.
The third part (para. 10) is prepared by the Technical Committee.

CONTENTS

1. OVERVIEW: ACTION IDENTIFICATION DATA

(Fill and update the table "Action identification data" attached at the end)

2. OBJECTIVES

COST 271 is an Action for the promotion, stimulation and co-ordination of the European research in ionospheric and plasmaspheric areas. The Memorandum of Understanding laid out the main objectives of the COST 271 Action as follows:

- to perform studies to influence the technical development and the implementation of new communication services, particularly for the GNSS and other advanced Earth-space and satellite-to-satellite applications,

- to develop methods and algorithms to predict and to minimise the effects of ionospheric perturbations and variations on communications and to ensure that the best models over Europe are made available to the ITU-R,

- to collect additional and new ionospheric and plasmaspheric data for now-casting and forecasting purposes,

- to stimulate further co-operation in the domain of ionospheric and plasmaspheric prediction and forecasting for terrestrial and Earth-space communications, including interactive repercussions on the corresponding standards in this field, taking into account the present and future needs of users.

3. TECHNICAL DESCRIPTION AND IMPLEMENTATION

At the outset of the project consideration was given to a wide range of technical questions of practical relevance. In addition, a special issue of the journal Quaderni di Geofisica (Ed. Cander and Zolesi, 2001) was published at an early stage. The aim was assess the current state of knowledge and to outline the activities in each participating country in the work areas of the COST 271 Action, with an indication of their significance. The research within COST 271 was then organised within four Working Groups arranged into at total of 15 Work Packages that are shown in Table 1. The activities within each of these areas are documented fully in the papers that follow in this volume that serves to make up the Final Report of the COST 271 Action.

Table 1. COST 271: Structure

WG1 - Impact of variability of space environment on communications	WG 2 - Assessment of space plasma effects for satellites applications	WG 3 - Ionospheric effects on terrestrial communications	WG 4 - Space plasma effects on Earth-space and satellite-to-satellite communications

WP 1.1 - Impact of space weather on communications	WP 2.1 - Plasma effects on GNSS applications	WP 3.1 - Effects of large scale ionospheric fluctuations on terrestrial communications, including remote sensing, radio localization and radar	WP 4.1 - Effects of space plasma variability and irregularities on Earth-space and satellite-to-satellite communication channels
WP 1.2 - Database and tools for nowcasting, forecasting and warning	WP 2.2 - Assessment of plasma propagation errors in navigation systems and merits and shortcomings of novel data sources	WP 3.2 - Effects of small-scale ionospheric irregularities, interference and noise on terrestrial communications	WP 4.2 - Development of algorithms and software to treat disturbances in Earth-space and satellite-to-satellite communications
WP 1.3 - Long term trends in the ionosphere and upper atmosphere parameters	WP 2.3 - Investigation of extremes of ionization	WP 3.3 - Mid-latitude ionospheric features in radio propagation models	WP 4.3 - Application of theoretical considerations to the study of space plasma effects
WP 1.4 - Upper atmosphere parameters monitoring for nowcasting and forecasting purposes		WP 3.4 - Development of methods and algorithms to minimize the deleterious effects of the ionosphere on terrestrial communications	WP 4.4 - Effects of the vertical and horizontal gradients of the electron density on Earth-space and satellite-to-satellite communication

Working Group 1: Impact of variability of space environment on communications

Space weather and its impact on terrestrial and space communications have drawn increasing attention in recent years. Four working packages were defined under this heading:

- **Impact of space weather on communication**: to identify present and future anticipated terrestrial and Earth space radio systems, to identify propagation phenomena which can lead to impairments of these radio systems that need to be modelled, to identify those space weather parameters that impact adversely and significantly on propagation conditions and to develop mitigation techniques.
- **Real-time satellite and terrestrial measurements for now-casting, forecasting and warning purposes:** to establish a space weather database

consisting of both past and new measurements and to use these measurements for the development of now-casting and forecasting propagation procedures and software tools.

- **Long-term trends in the ionosphere and upper atmosphere parameters:** to investigate and understand the nature of the long-term behaviour of all ionospheric regions and potential effects of the long-term trends on prediction models.
- **Upper atmosphere parameters monitoring for nowcasting and forecasting purposes**: to develop methods to extract thermospheric parameters using routine ionospheric observations and to develop a version of the Self-Consistent method which would use routine electron density ionosonde profiles to monitor the upper neutral atmosphere above Europe.

Some initial activities on improved robustness of prediction, which were separated as additional work package at the beginning of the investigation, were later incorporated into the studies of real-time satellite and terrestrial measurements for nowcasting, forecasting and warning purposes.

Working Group 2: Assessment of space plasma effects for satellites applications

The distribution and dynamics of the ionospheric plasma have a significant impact on GNSS applications for navigation, positioning and remote sensing of the Earth's atmosphere. Three working packages were included in this area:

- **Plasma effects on GNSS applications**: to explore the amplitude and dynamics of horizontal structures in TEC by combining data derived by different measuring techniques (ground- and space-based GPS, NNSS, satellite altimetry), in particular under perturbed ionospheric conditions, to detect and analyse TID's and the resultant phase fluctuations that degrade the accuracy in GNSS applications under various geophysical conditions.
- **Assessment of plasma propagation errors in navigation systems and merits and shortcomings of novel data sources:** to assess ionospheric effects in non-ionospheric applications of GNSS signals, a) ionospheric influences in the use of GNSS occultation for stratosphere/troposphere applications, b) the effects of higher order ionospheric propagation errors in advanced ground based applications, like water vapour retrieval.
- **Investigation of extremes of ionization:** to deal with observations aimed to come up with reasonable occurrence statistics when possible, to guide the data collection, to collect well-documented extremes and to provide a list of criteria to define type and nature of the extreme cases.

Working Group 3: Ionospheric effects on terrestrial communications

Additional knowledge of the effects of large-scale ionospheric fluctuations, small-scale ionospheric irregularities, noise and interference on terrestrial communications including remote sensing, radio location techniques and radar is required. Four working packages were established within this general area:

- **Effects of large-scale fluctuations on terrestrial communications:** to determine at regional/global scale the percentage contribution to the variability of main ionospheric parameters.

- **Effects of small-scale ionospheric irregularities, interference and noise on terrestrial communication, including remote sensing, radio location and radar:** to give a definition of the classes of irregularities to be taken into account, an analysis of their effects on the performances of the systems, the establishment of a catalogue of the known characteristics and of the available equipment for the studies.
- **Mid-latitude ionospheric features in radio propagation models:** to assess the role of ionospheric and plasmaspheric irregularities of various dimensions in radio propagation at middle latitudes.
- **Development of methods and algorithms to minimize the above-referred effects on terrestrial communications, including remote sensing, radio location and radar:** to identify the most important problems due to the ionospheric characteristics and variability, to develop possible methods, if any, to minimize the deleterious effects and when possible, propose specific algorithms..

Working Group 4: Space plasma effects on Earth-space and satellite-to-satellite communications

Space plasma variability and irregularities effects are of increasing interest to the practical operation of satellite systems. Four working packages were included under this topic:

- **Effects of space plasma variability and irregularities on Earth-space and satellite–to-satellite communication channels**: to develop a database of space plasma variability and irregularities characteristics, using both measurements and results from theoretical models and to review the effects of variability and irregularities on communications, considering different locations of transmitter and receiver.
- **Development of algorithms and software to treat with disturbances in Earth-space and satellite-to-satellite communications:** to forecast TEC in time and space from 1 to 24 hours in advance by using neural networks, signal processing and other relevant techniques and to obtain quantitative description of the TEC variability and develop algorithms for nowcasting and forecasting.
- **Application of theoretical considerations to the study of space plasma effects:** to study the ionospheric disturbances generated by natural electromagnetic and electrostatic instabilities.
- **Effects of the electron density vertical and horizontal gradients on satellite communications:** to assess the effect of electron density gradients in the slant to vertical time delay conversion in Earth-space communications, to assess the effect of electron concentration gradients in satellite-to-satellite communication, to validate and improve existing topside electron concentration models by using the large Russian topside profiles database and to validate models of electron concentration profiles based on instantaneous (nowcasting) maps of basic parameters from vertical soundings data by using IGS slant TEC data and tomographic reconstruction.

4. PARTICIPATION AND COORDINATION

4.1. Management Committee

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CNRS, Grenoble, France
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University of Leicester, United Kingdom
University of Nottingham, United Kingdom
University of Sheffield, United Kingdom
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Institute of Terrestrial Magnetism, Ionosphere and Radiowave Propagation, Russia
University of Saint Petersburg, Russia
University of Massachusetts Lowell, USA

4.3. Meetings of the Management Committee

9 October 2000, Brussels, Belgium, (Inaugural Meeting)
24 – 27 January 2001, Trieste, Italy
25 – 29 September 2001, Sopron, Hungary
6 - 9 March 2002, Graz, Austria
1 - 5 October 2002, Faro, Portugal
27 February –1 March 2003, Rome, Italy
23 – 27 September 2003, Spetses, Greece
18 - 20 March 2004, Roquetes, Spain
26 - 28August 2004, Abingdon , UK

4.4. Meetings of the Working Groups

26 March 2001	EGS Meeting, Nice, France
23 April 2002	EGS Meeting, Nice, France
20 August 2002	URSI Meeting, Maastricht. The Netherland
10 April 2003	EGS/AGU Meeting, Nice
21 April 2004	EGU Meeting, Nice

4.5. Short-term scientific missions

A. Belehaki from NOA to RAL, UK
E. Turker Senalp from METU to RAL, UK
G. Miro from INTA to Aristotelian University of Thessaloniki, Greece
V. Depuev from IZMIRAN to Abdus Salam ICTP, Italy
I Tsagouri from NOA to RAL, UK
N Malan from The University of Wales, Aberystwyth to DLR, Germany
D Buresova from Institute of Atmospheric Physics to RAL, UK
M Cuerto from Universidad Complutense de Madrid to DLR, Germany
M.Materassi from CNR to SRC, Poland

Moreover, the following young scientists: P. Sauli (Czech Republic), I. Tsagouri (Greece), M. Cueto (Spain), E. Turker Senalp (Turkey) and M. Rieger (Austria) were invited to attend the 2nd COST 271 workshop held in Faro, Portugal, 2 - 4 October 2002.

Finally, Chairman and Vice Chairperson attended the E-STAR meeting on 1-2 December 2003 in Strasbourg and joint ESA/COST271/COST274/SWWT/E-STAR/FP6: SW-RISK meeting on 27 February 2004 in Paris, respectively.

5. RESULTS

The major achievements of cost 271 can be summarized as follows:

- A survey has been carried out of modern radio systems in different frequency bands, within the context of international regulations and the propagation phenomena that can lead to system impairments, together with the space-weather effects that can cause significant adverse impacts on propagation conditions that need to be modelled.
- Ionospheric stations over Europe have made a vital contribution in maintaining the high standard of vertical-incidence measurements and providing data on a regular basis. Collection and distribution of the historical, new and prompt ionospheric data has been carried out at both the Rutherford Appleton Laboratory (http://www.wdc.rl.ac.uk/cgi-bin/digisondes/cost_database.pl) and the Space Research Centre (http://www.cbk.waw.pl/rwc). In addition, there has been continuing support of the limited database of past ionospheric observations that was developed under the previous COST Action 251 (http://cost251.ictp.trieste.it/).
- A database of EISCAT observations from 1981 to 1999 has been developed at the University of Grenoble (http://www-eiscat.ujf-grenoble.fr).
- Operational services for nowcasting and forecasting the state of the ionosphere over Europe are now available at the Regional Warning Center in Warsaw (http://www.cbk.waw.pl/rwc) and the Rutherford Appleton Laboratory (http://ionosphere.rcru.rl.ac.uk);
- Modelling techniques has been formulated, leading to experimental and real-

time operational services involving new mathematical methods and computational tools for the forecasting and regional mapping of ionospheric characteristics.

- Improvements have been made to existing understanding of the physical mechanisms responsible for possible long-term trends in the Earth's ionospheric and atmospheric parameters that may possibly link such trends with anthropogenic activities.
- Studies have been carried out to advance knowledge of the structure and dynamics of the upper atmosphere and provide tools needed for the investigation of thermospheric-ionospheric interactions under various geophysical conditions.
- Models, and other tools to assess ionospheric effects in non-ionospheric applications of GNSS signals, have been investigated at the University of Graz (http://www.uni-graz.at/igamwww/cost271/) including (a) ionospheric influences in the use of GNSS occultation for stratosphere / troposphere applications and b) the effect of higher-order ionospheric propagation errors in advanced ground-based applications, like water vapour retrieval.
- GPS-based regional maps and the TECEDA data bank are now available at the Deutsches Zentrum für Luft und Raumfahrt (http://www.kn.nz.dlr.de).
- Collection has been started of examples of ionospheric extremes and anomalous cases with unusually high or low electron content values, anomalous gradients and variations that could be attributed to the influence of magnetic storms, travelling ionospheric disturbances (TIDs) and other as yet partially unexplained effects.
- Investigation has been made of gravity and planetary waves at mid-latitudes, responsible for some of the residual uncertainty in ionospheric radio-wave propagation predictions, with a view to identifying patterns to improve the accuracy of forecasts for telecommunication purposes.
- A physically-based software simulator has been developed for the HF ionospheric reflection channel and UHF simulators for transionospheric channels, which overcome the limitations of existing empirically-based models.
- Studies have been carried out leading to better understanding of the behavior of the ionospheric F1-region, sporadic-E (Es) and spread F phenomena at European middle latitudes under geomagnetic storm conditions.
- Measurements and simulations have been made and results of importance to applied radio systems obtained, relating to the propagation of HF radio waves over northern European paths, where ionospheric effects impose large Doppler and delay spreads on the propagating signal.
- A heterogeneous array has been investigated to improve HF transmission, offering the possibility to transmit images via the ionospheric channel by providing an increase of the data rate of 15 kHz within a 3 kHz bandwidth (QAM-64) without coding or interleaving.
- Improvements to the GISM model include use of the multiple phase screen technique to give statistical characteristics of transmitted signals; fade duration and other parameters like the probability of signal loss of lock. Maps of scintillation index S4 and standard deviations of the phase fluctuations can be produced.
- Algorithms and software tools have been developed to treat disturbances in Earth-space and satellite-to-satellite communications;
- Studies have been made of plasma effects in the magnetosphere-ionosphere-

thermosphere system generated by different natural processes and by human activity.
- Information has been gathered about effects of the vertical and horizontal gradients of the electron density on Earth-space and satellite-to-satellite communication.
- Model simulation studies have been made of extreme propagation effects on GPS-to-geostationary satellite ray paths.

6. DISSEMINATION OF RESULTS

6.1. Publications and Reports

Most of the papers reporting activities of the COST271 Action have been published in the following special issues:

1. 1st COST271 Workshop CD Proceedings on "Ionospheric Modelling and Variability studies for Telecommunication Applications", 25 - 27 September 2001, Sopron, Hungary.

2. Special volume of Acta Geophysica Hungarica devoted to the selected papers from the COST271 Workshop on "Ionospheric Modelling and Variability studies for Telecommunication Applications", Volume 37, Numbers 2-3, 2002.

3. Special volume of Annals of Geophysics devoted to the selected papers from the XXVI EGS General Assembly Session on "Ionospheric variability and modelling", Volume 45, N 1, February 2002.

4. 2nd COST271 Workshop CD Proceedings on "COST271 Products for ITU-R and other radiocommunication applications ", 2 - 4 October 2002, Faro, Portugal.

5. 3rd COST 271 Workshop Proceedings on "Significant results in COST271 Action, 23 – 27 September 2003, Spetses, Greece, published on line at the COST271 web site.

6. Special volume of Annals of Geophysics devoted to the selected papers from the EGS/AGU General Assembly Session on "Effects of the Ionosphere on Terrestrial and Earth-Space Communications", in press 2004.

7. COST 271 Final Report: Supplement to Volume 47, N. 2, Annals of Geophysics, 2004.

6.2. Conferences and Workshops

1st COST271 Workshop on "Ionospheric Modelling and Variability studies for Telecommunication Applications", 25 - 27 September 2001, Sopron, Hungary

2nd COST271 Workshop on "COST271 Products for ITU-R and other radiocommunication applications", 2 - 4 October 2002, Faro, Portugal
3rd COST271 Workshop on " Significant results in COST271Action, 23 – 27 September 2003 , Spetses, Greece

6.3. Web site

The Web site of the COST271 Action has been active since the beginning of the action on the following address:

http://www.cost271.rl.ac.uk/.

It is maintained by Mrs. A. Vernon at Rutherford Appleton Laboratory and contains the COST271 Action main info documents as the management structure, the Minutes of the Management Committee meetings, the Call for papers and other relevant documents for the action in addition to the related web links.

6.4. Scientific and Technical Co-operation

The research links established as part of previous COST 238 and 251 actions have led to a number of bilateral and multi-lateral collaboration, which have continued in the COST 271 Action as well. In addition, participants of this action have been very active in different international projects. There is a significant participation of Action members from Working Group 1 in ESA Space Weather Program, in particular in its Space Weather Working Team (SWWT) and the Pilot Projects scheme.. The URSI Beacon Satellite Group closely linked to the work of the second and fourth Working Group of this action, provides important links between ionosphere, plasmasphere and upper atmosphere scientists, engineers and users of satellite beacon applications. Several COST271 Group members are advisers and observers in the International Geodynamics Service (IGS) and some of its offspring organisations like the GPS-IONO group.

Close links to several organizations that deal with GNSS (presently mainly GPS) applications for navigation and surveying have been established. There is a strong involvement of Action members in ESA/ESTEC projects: (a) in connection with EGNOS and GALILEOSAT and (b) in connection with assessment studies for the use of GNSS occultation for atmospheric and ionospheric research. There is an active collaboration of Action group members in INTAS projects with Russian and Ukrainian participation. Finally, it should be mentioned a collaboration with the International Reference Ionosphere (IRI) Working Group by carrying out international Task Force Activities at the Abdus Salam ICTP on improvements of the IRI model. Moreover participants of this action have given a considerable contribution to the international HIgh RAte Campaign (HIRAC) of the International GPS and in validation of the CHAMP results.

Throughout the duration of COST271 participants have become aware, in some cases without having prior knowledge, of other groups in other countries with the same interests, complementary resources and levels of expertise. This has led to a number of bilateral and multi-national collaborations that most probably would not have taken place without the existence of COST271. These collaborations have undoubtedly been strengthened by the Short-Term Missions, which have enabled participants from one organisation to work for a short time alongside colleagues in the host organisation on common limited-objective tasks. At the same time to see the peripheral work in progress, the teams involved, aspirations and future goals are strong incentives for extended common activities. Such collaborations are not specifically mentioned within COST271 publications, but there are a good number of these. Joint Italian-Greek organised meetings in Crete can be cited. Other Bulgarian-Belgium, UK-Serbia, Russia-Poland, Germany-Greece, UK-France, UK-Russia, UK-Greece, Turkey-Italy and Spain-Italy collaborations either already have or are continuing to take place. Management Committee meetings have always included an agenda item for those present to be made aware of forthcoming meetings and opportunities for future collaborations.

6.5. Transfer of results

Designed to meet the needs of Europe, this action made an impact to the work of the International Telecommunication Union - Radiocommunication Sector (ITU-R) at http://www.itu.int/ITU-R/. In particular Study Group 3 on Radiowave Propagation at http://www.itu.int/ITU-R/study-groups/index.asp and its Working party 3L on Ionospheric Propagation at http://www.itu.int/ITU-R/study-groups/rsg3/index.asp through major contributions to Recommendations, provision of data for validation of prediction models for Europe and by a leading role in Working Party 3L (Ionospheric Propagation). Further steps will be taken to make the most applicable results available to ITU-R in due course. Furthermore, a number of potential synergies have been exploited to transfer the COST271 Action results to different national and international bodies, operators and industry dealing with the European space weather issue, ionospheric impact on GNSS and applications of the ionospheric prediction and forecasting in planning and spectrum management purposes.

6.6. Contacts in the ERA

Part of the COST271 Action is involved in the DIAS (Digital Upper Atmosphere Server) eContent framework activity for the period 2004-2006 as well as in and the ROSE project on establishing Europe an international geophysical observatory at Gaudos. The pilot project involving Italian, Greek and UK partners named Geomagnetic Indices Forecasting and Ionospheric Nowcasting Tools (GIFINT) and the DLR pilot project have been financially supported by the ESA the framework of the SWENET (Space Weather European Network) program

7. ECONOMIC DIMENSION

Cost per signatory per year:

1.5 person/year: Engineer, Researcher	**150.000 €**
- person/year: Technician	**-**
0.5 person/year: PhD, Student, Secretary	**15.000 €**
Equipment and material costs	**-**
Travel	**5.000 €**
Total per signatory per year	**170.000 €**

Funds received from the COST budget for each year and for the entire duration of the Action

Action COST grant for 2001/2002

1st MC Meeting ,Trieste, Italy , 24-27January 2001………………………………… 8,726.93

2nd MC Meeting and Workshop, Sopron, Hungary 25-29, September 2001……….25,958

3th MC Meeting ,Graz, Austria 7-9 March 2002 …………………………………...22,586.03

Short-term Scientific Mission payments to 5 participants   ………………………3,600

Postage + book of abstracts + CD Workshop Proceedings……………………………1,000

Secretariat, postage + consumables……………………………………………………8,129.04

Total in the year ………………………………………………………………...70,000

Action COST grant for 2002/2003

4th MC Meeting and Workshop 1-5 October 2002, Faro, Portugal…………………..26,942.05

Young Scientists reimbursement for Faro, Portugal……………. ……………………4,164.59

Postage + book of abstracts + CD Workshop Proceedings…………………………….1,000

5th MC Meeting 27 February –1 March 2003 , Rome, Italy…………………………..19,244.57

Payment to Chairman to attend COST271/RA, one-day Workshop (UK)

Payment to Chairman and Vice Chairperson for June 2003 TC-TIST-MC

And Short-term Scientific Mission payments   to 5 participants……………………5,001.00

Spetses, Greece Workshop grant ………………………………………………4,000.00

Secretariat, postage + consumables……………………………………………………..

3,647.79

Total in the

year……………………………………………………………………64,000.0

Action COST grant for 2003/2004

5th MC Meeting and Workshop 23 – 27 September 2003, Spetses, Greece ……………8573,06
6th MC Meeting 8 - 20 March 2004, Roquetes, Spain……………………………….20611,63
Observatori de l'Ebre MC grant ……………………………………………………...2000,00
TC-TIST Bucarest 808,84
Total Secretariat ……………………………………………………………………..13005,00

Total in the year…………………………………………………………….…..44998.53

Total financial support excluding the final

period,……………………………….178998.53

8. SELF EVALUATION

The expanding need for new communications services, especially those involving ionospheric HF communications, satellite communications and navigational systems, imposes increasing demands for the continuous monitoring and better understanding of the propagation effects imposed by the Earth's upper atmospheric that play important roles in determining the characteristics and reliability of the radio systems. There is a requirement to develop means to predict regular behaviour and to minimise the disturbing effects over a wide range of propagation conditions. Within this context, the COST 271 Action on "Effects of the upper atmosphere on terrestrial and Earth-space communications" has made a significant impact in a number of areas:

(a) Progress has been made in the examination of the need for information on propagation effects on both currently-operational and future-anticipated terrestrial and Earth-space radio systems that can be affected by space-weather phenomena, with emphasis being placed on characterisation of the relevant phenomena and their associated consequences. A detailed report was produced on modern radio systems in different frequency bands, within the context of international regulations and the propagation phenomena that can lead to system impairments, together with the space-weather effects that can cause significant adverse impacts on propagation conditions that need to be modelled.

(b) Specific studies have been undertaken in response to the terms of references of COST271 Action Work Packages leading to: (i) new modelling techniques for experimental and real-time operational services for nowcasting and forecasting the state of the ionosphere over Europe available at the Regional Warning Center in Warsaw (http://www.cbk.waw.pl/rwc) and the Rutherford Appleton Laboratory (http://ionosphere.rcru.rl.ac.uk); (ii) new models and tools to assess ionospheric effects in non-ionospheric applications of GNSS signals, available at the University of Graz (http://www.uni-graz.at/igamwww/cost271/); (iii) GPS-based regional maps and the TECEDA data bank available at the Deutsches Zentrum für Luft und Raumfahrt (http://www.kn.nz.dlr.de); (iv) development of a physically-based software simulator for the HF ionospheric reflection channel and UHF simulators for transionospheric channels that overcome the limitations of existing empirically-based models; and (v) development of a heterogeneous array to improve HF transmission, offering a possibility to transmit images via the ionospheric channel by providing an increase of the data rate of 15 kHz within a 3 kHz bandwidth (QAM-64) without coding or interleaving.

(c) New data have been collected and mathematical methods and computational tools developed. In particular, a vital contribution has been made in maintaining the high standard of ionosonde measurements at European stations and providing the historical, new and prompt ionospheric data on a regular basis at both the Rutherford Appleton Laboratory (http://www.wdc.rl.ac.uk/cgi-bin/digisondes/cost_database.pl) and the Space Research Centre (http://www.cbk.waw.pl/rwc). In addition a new database of EISCAT observations from 1981 to 1999 has been developed at the University of Grenoble (http://www-eiscat.ujf-grenoble.fr).

(d) Dedicated studies have made a significant input to the emerging science of the impact of on space weather on the terrestrial environment and advanced technology as those related to: new measurements and simulations of the propagation of HF radio waves over northern European paths; examination of examples of ionospheric anomalous cases and their extreme propagation effects on GPS-to-geostationary satellite ray paths; investigation of gravity and planetary waves at mid-latitudes, responsible for some of the residual uncertainty in ionospheric radio-wave propagation predictions; and studies of plasma effects in the magnetosphere-ionosphere-thermosphere system generated by different natural processes and by human activity.

(e) Results of significance have been made available to the ITU-R Study Group 3 for incorporation into international recommendations in cases of the NeQuick ionospheric model and the GISM scintillation model.

(f) The results from these investigations have been discussed at three Workshops and published to the considerable benefit of both participating and other organisations;

Full details of these achievements have been given in the COST271 Final Report and placed on the COST271 Web site (www.cost271.rl.ac.uk). In addition, the CD containing this Final Report includes the full bibliography, addresses of participants and relevant web links.

The COST 271 Action has been very successful in bringing together in collaborative studies many researchers who collectively represent much of the available European expertise on the effects of the upper atmosphere on radio systems. The significant results and advances in knowledge and understanding stemming from COST 271 have been summarized here. In addition, a proposal has been outlined for new investigations within the COST Telecommunications, Information Science and Technology framework into the mitigation of such propagation effects on practical communications systems.

9. EVALUATION

Evaluation panel and evaluation procedures

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Evaluation period: August/October 2004-08-28

Evaluation meeting: Abingdon, United Kingdom, 27-28 August 2004

All the solicited documents to the COST 271 Action chairman and vice-chairperson were made available in advance to the evaluators. In particular the COST 271 Action Final Report draft, the Final Evaluation Report corresponding information, including self-evaluation, and copies of the presentations to the Final Meeting. This information was complemented by the notes taken by the evaluators during the different presentations held during the two-day COST 271 Final Meeting.

Results versus objectives

The main objectives of the COST 271 project were:

(1) To perform studies to influence the technical development and implementation of new communication services, particularly for Global Navigation Satellite Systems and other advanced Earth-space and satellite-to-satellite applications.

(2) To develop methods and algorithms to predict and minimise the effects of perturbations and variations in the ionosphere on communications and to ensure that the best European models are made available to ITU-R.

(3) To collect new and additional data on the ionosphere and plasmasphere for now-casting and forecasting purposes.

(4) To stimulate further co-operation in predicting and forecasting the ionosphere and plasmasphere, interactively developing the corresponding standards in this field to take into account users' present and future needs.

The four general objectives have been fulfilled during the 4 years of the COST 271 Action, by means of the very active work of four **Working Groups:**

WG1: Impact of Variability of Space Environment on Communications.

Indeed, the objectives of this WG have been accomplished:

1) The collection of historical and new ionospheric and plasmaspheric data for now-casting and forecasting purposes, and the development of methods and algorithms to monitor, predict and minimize the effects of ionospheric perturbations and variations on communications.
2) The stimulation of cooperation, in European level, in the domain of ionospheric and plasmaspheric prediction and forecasting for terrestrial and Earth-space communications.

WG2: Assessment of Space Plasma Effects for Satellites Applications.

In this WG, the initial goals were established as follows: “Cost 271 Working Group 2 will analyse and assess the effects of space plasma on the accuracy and reliability of Global Navigation Satellite Systems (GNSS) and other satellite systems, in particular for planning advanced applications. The work will concentrate on the effects of the largescale distribution of electron density. Experimental data will be complemented by models and by theoretical considerations for developing appropriate software and algorithms."

The 3 Work Packages into which this WG was divided are:

1) Plasma effects on GNSS applications: completely finish
2) Assessment of plasma propagation errors in navigation systems and merits and shortcomings of novel data sources: mostly finish.
3) Investigation of extremes of ionisation, completely finish.

WG3: Ionospheric Effects on Terrestrial Communications.

Regarding to the main objectives of this Working Group (study the effects and prediction/mitigation of large and small-scale ionospheric fluctuations on terrestrial communications), main results have been achieved in COST 271 in the following areas:

1) Large-scale fluctuations of gravity and planetary waves
2) Magnetic storm effects on the F1 region ionosphere,
3) The sporadic E-layer and spread-F phenomena,
4) TheHF radio wave propagation over northerly paths,
5) Development of a new type of HF channel simulator
6) How to increase the bit rate in ionospheric radio links.

In general, substantial progress was achieved but still some problems remain open for future investigations.

WG4: Space Plasma Effects on Earth-Space and Satellite-to-Satellite Communications.

Both goals have been achieved: the assessment of the effects of variability and irregularities in space plasma on satellite systems and the development of algorithms to treat both variability and disturbances in Earth-space and satellite-to-satellite communications.

<u>Outcome and achievements</u>

Many results and achievements have been obtained during this COST Action.

Just to mention some of them:

-Development of several databases and real-time, near real-time and historical broadcasting data facilities (EISCAT at Univ. Grenoble, ionospheric forecasting and newcasting at Regional Warning Center at Warsaw and RAL, TECADA at DLR,…).

-Development of models for other communities of users (Ionospheric model developed by DLR for the GNSS EGNOS Test Bed, NeQuick model developed by Univ. Graz and Abdus-Salam Institute of Trieste for Galileo ionospheric corrections,…).

-The long-term trends in several ionospheric parameters have been fitted, and as a consequence its non-significance for typical prediction models is concluded.

-The occurrence of gravitational waves due to in-situ effects (such as those with solar terminator origin) follows a quite regular pattern and could be included in future prediction models for users.

-The transmission of information in the ionospheric channel (such as images) has been significantly improved and tested.

Moreover the dissemination of results has been very important:

- Open literature publications, specialist topics and overview surveys, many of them in international journals with impact factor.
- International Conference Presentations and Proceedings.
- Workshop Proceedings (published as hard copy, CD's and Web-based).
- Annual Progress Reports.
- Final Report, including extensive reference lists.

Impact of the Action

- Provide ionospheric models to 3rd parties / organizations (such as ITU-R, ESA, EUROCONTROL) that are being used or will be used by other communities of scientific and technological users (such as general GNSS users or particularly civil aviation users).
- It permits teams of viable size to tackle identified tasks, with the benefits of the synergy with other experts in problem solving and the training and encouragement for young scientists to the field, working with groups in other countries. This was achieved by an appropriate number of Short-term Missions.

European added-value

-In general, it has contributed very significantly to form a body of ionosphere experts to be available at minimum cost to solve problems that future telecommunication systems may identify.

-In particular, it has helped to provide an important contribution in several of the more important European technological projects, such as the EGNOS augmentation system for GNSS navigation in civil aviation, and the future European GNSS Galileo system, among others.

Coordination and management

The project was managed in an efficient way, in spite of the great number of participants. In addition to the chairman, the co-chair person played a very active role. The Working Group leaders helped significantly to this task. Also the administrative management was handled very effectively.

Dissemination of results

The results have been very actively disseminated, in form of scientific papers (more than 150 published in international journals with impact factor), 3 international workshops attended by a great number of scientists. The proceedings of these workshops have been published separately. The Final Report COST271 Action is being printed as a supplement to Annals of Geophysics, and will find wide distribution.

Several Web sites have been developed and maintained during the action supporting both, the distribution of results and the real-time data.

Strengths and weaknesses

Strengths:

Very active work of the different participants collaborating in a very efficient way both in Europe and worldwide, significant and tangible results found. In particular, action has been successful in keeping together in collaborative studies many researchers who collectively represent much of the available European expertise on the effects of the upper atmosphere on radio systems.

Weaknesses:

Certain overlapping of activities may be related with the lack of concretion of certain goals and work packages descriptors.

Recommendations

Action finalised with outstanding success. In order to not lose the expertise which has been collected throughout during the 4 years of COST271 it is strongly recommended to introduce a new action in the field of Ionospheric Physics and Radio Wave Propagation, with somewhat different emphasis.

Action COST 271 was the third in a series of very successful actions in the field of the radio wave propagation of the Ionosphere (“Success Story”). It is strongly recommended that further elaboration of the results obtained hitherto is encouraged: A follow-up action “Mitigation of Ionospheric Effects on Radio Systems” (MIERS) has been proposed, which would fulfill this purpose.

Action Identification Data

COST Action 271 *Title* **Effects of the Upper Atmosphere on Terrestrial and Earth-Space Communications**

TC Recommendation: 29 October 1999
CSO Approval: 10 December 1999
Start date: 16 August 2000
Duration: 48 months
Extension: none
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First MC meeting: 9 October 2000
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Evaluation Report:
TC Evaluation:

Number of signatories: 17

Signatories and date of signature:

Austria 7 June 2000	Greece 31 May 2000	Poland 10 May 2000
Belgium 1st September 2002	Hungary 23 May 2000	Portugal 26/10/2000
Bulgaria 16 August 2000	Iceland	Romania
Croatia	Ireland	Slovakia
Cyprus	Italy 3 July 2000	Slovenia
Czech Rep. 26 June 2000	Latvia 9 June 2000	Spain 10 May 2000
Denmak	Lithuania	Sweden
Estonia	Luxembourg	Switzerland
Finland 6 September 2000	Malta	Turkey 26 May 2000
France 10 May 2000	Netherlands	United Kingdom 29 June 2000
Germany 17 May 2000	Norway	Serbia-Montenegro Fed. Rep. 1/03/2002

Institutes of non-COST countries:

1) Russian Academy of Sciences (IZMIRAN, RUSSIA)
2) University of St Petersburg (RUSSIA)
3) University of Massachusetts Lowell (USA)

Area: Telecommunication Information Science and Technology

Action Web site: http://www.cost271.rl.ac.uk/

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External Evaluator: Dr. Manuel Hernandez-Pajares, Technical University of Catalonia, Spain

(1) Date of the first MC meeting

(2) When the report is received by TC Secretariat