Report on Researchers' Requirements

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1. Executive Summary

The EARNEST foresight study has looked at the expected development of research and education networking in Europe over the next 5-10 years. The study was carried out between March 2006 and November 2007. EARNEST was funded by the European Union through the GN2 project, which also provides the funding for the current generation of the pan-European research and education backbone network, GÉANT2.

The aim of EARNEST was to provide input for initiatives that could help to keep the evolution of European research networking at the forefront of worldwide developments and enhance the competitiveness of the European Research Area. EARNEST has prepared the ground for the planning of the development of research and education networking infrastructure and services after the completion of the GN2 project, at the local, national, European and intercontinental level.

EARNEST can be seen as the successor of the very successful study that was carried out in the SERENATE project in the period from May 2002 until December 2003. The results of the SERENATE study, and in particular the recommendations in its Summary Report, have been very influential on the planning and development of research and education networking in Europe in subsequent years.

After an initial preparatory phase, the EARNEST work has focused on seven study areas: researchers' requirements, technical issues, campus issues, economic issues, geographic issues, organisation and governance issues, and requirements of users in schools, the healthcare sector and the arts, humanities and social sciences. Reports have been published on the results of each of these sub-studies, as well as an additional report on regulatory issues. The EARNEST study is rounded off by a Summary Report that contains recommendations for the relevant stakeholders.

The current report presents the results of a large-scale survey of researchers' requirements. The survey is based on a broad questionnaire that was addressed to more than 11,000 scientists and an interview stage that involved some 30 distinguished scientists and aimed for more detailed replies. Data were collected and statistically prepared by the independent survey company Technopolis Ltd. The compilation of the results, the analysis and the production of the survey report were co-ordinated within the Physical and Engineering Sciences unit of the European Science Foundation, with input from independent scientists and the EARNEST Panel.

The response rate of the scientific community was high (approximately 39%). Basic knowledge of tools and use of services was found to be widespread. However, levels of expertise were found to be very divergent and accompanied by a clear unawareness of technical details. The need for special training for end-users was expressed. On the other hand, services and related technology as well as possible connectivity bottlenecks were not seen as constraints. This reflected an overall high degree of satisfaction with current services. The majority of respondents believe that those services will lead to a significant increase in scientific, networking and collaboration activities within the next decade. Similarly, the number of Virtual Organisations is foreseen to increase. However, standardisation, quality control and security issues should be addressed. It is foreseen that effective exploitation of trans-national connectivity and the resulting capability to make the correct decisions will become increasingly critical to the success of individual projects and research strategies.

2. Introduction

2.1 Background

At its meeting in Lisbon in March 2000, the European Council, facing the challenges posed by globalisation and the emergence of the knowledge-based economy, declared its intention to turn the European Union into the world's most dynamic knowledge-based economy by the year 2010. Clearly, this cannot happen overnight. It also cannot happen without substantial increases in the level of research activity in Europe and its efficiency.

Within Europe, cyber-infrastructures - i.e., a pan-European research networking infrastructure consisting of interconnected national research networks, combined with high-performance computing facilities and the use of associated Grid technologies - are seen as essential strategic areas for the development of the European Research Area (ERA). They must be supported at a European level by facilitating the integration of national efforts. The pan-European backbone research network, currently known as GÉANT2, is at the basis of this international infrastructure[1].

Funding for GÉANT2 comes from the GN2 project. That project began in 2004, and was scheduled to run for four years. Its core objective is to plan, build and operate a multi-Gigabit pan-European backbone research network interconnecting Europe's National Research and Education Networks (NRENs)[2]. In addition to this GÉANT2 network, the project includes:

- an integrated research programme;
- the development of support services for network users;
- initiatives to monitor and address disparities in networks across Europe;
- a comprehensive study into the future of European research and education networking, known as EARNEST.

The EARNEST foresight study has looked at the expected development of research and education networking in Europe over the next 5-10 years. The study was carried out between March 2006 and November 2007. The aim of EARNEST was to provide input for initiatives that could help to keep the evolution of European research networking at the forefront of worldwide developments and enhance the competitiveness of the European Research Area. EARNEST has prepared the ground for the planning of the development of research and education networking infrastructure and services after the completion of the GN2 project, at the local, national, European and intercontinental level.

EARNEST can be seen as the successor of the very successful study that was carried out in the SERENATE project in the period from May 2002 until December 2003. The results of the SERENATE study, and in particular the recommendations in its Summary Report, have been very influential on the planning and development of research and education networking in Europe in subsequent years.

After an initial preparatory phase, the EARNEST work has focused on seven study areas: researchers' requirements, technical issues, campus issues, economic issues, geographic issues, organisation and governance issues, and requirements of users in schools, the healthcare sector and the arts,

1. *Since 1993 there have been five consecutive generations of the pan-European research backbone network: EuropaNET, TEN-34, TEN-155, GÉANT and GÉANT2.*

2. *In this report, the acronym "NRENs" is used to denote National Research and Education Networking organisations as well as the national networks provided by them.*

humanities and social sciences. Reports have been published on the results of each of these sub-studies, as well as an additional report on regulatory issues. The EARNEST study is rounded off by a Summary Report that contains recommendations for the relevant stakeholders.

2.2 Objectives

The study of researchers' requirements was implemented by the European Science Foundation (ESF) as a Third Party in the GN2 project through its Physical and Engineering Sciences (PESC) unit. The main objectives of the study were to

- investigate the current and future requirements of researchers and academic teachers in respect of data networks and associated services, applications and IT facilities;
- provide evidence of the impact that the development of research and education networking and services has had in recent years on research in various disciplines;
- explore issues related to existing networks, performance issues, and developments that would be necessary in order to meet anticipated future needs.

2.3 Methodology

2.3.1 Contributors and procedure

The European Science Foundation provides a platform for its member organisations to advance European research and explore new directions for research at the European level. Established in 1974 as an independent non-governmental organisation, the ESF currently serves 74 member organisations across 30 countries. The ESF has offices in Strasbourg (its headquarters) and Brussels. With its emphasis on a multidisciplinary and pan-European approach, the ESF provides the leadership to open new frontiers in European science. ESF activities include providing advice on science policy (Science Strategy), stimulating co-operation between researchers and organisations to explore new directions (Science Synergy) and the administration of externally funded programmes (Science Management). The ESF covers all scientific disciplines: physical, chemical and engineering sciences, life and environmental sciences, medical sciences, humanities and social sciences. Its political independence allows the ESF to represent objectively the common priorities of its member organisations.

As part of the EARNEST study of researchers' requirements, the ESF commissioned Technopolis Ltd. to undertake a two-stage survey and to provide a statistical evaluation of the results. Stage 1 consisted of a single large-scale online survey directed at more than 11,000 professional scientists working across Europe. Its objective was to investigate their current and future requirements with respect to data networks and associated services. The full questionnaire is presented in Appendix 1. Stage 2 followed on directly and was smaller in scale but more focused than the earlier part of the study. It involved follow-up interviews with 30 respondents to examine more thoroughly the issues arising from the first stage.

Technopolis Group was founded in 1989 and is one of Europe's best-established research and innovation policy consultants. The Group has a comprehensive knowledge of the European landscape of research and innovation policy as well as a track record in the evaluation of research and networking policies and programmes[3].

3. *See www.technopolis-group.com for more information.*

The statistically evaluated results were discussed and conclusions for the current report were drawn in several meetings of the EARNEST Panel and with independent scientists from the ESF's PESC area. Authors of the report are Thibaut Lery and Patrick Bressler of the PESC unit of the ESF, with contributions from Technopolis Ltd., Ian Butterworth, Stavros Farantos and Simone Meloni.

2.3.2 The large-scale survey

The survey aimed to collect factual information as well as opinions from active researchers who have direct knowledge of, and experience and involvement with, the use of data networks and related services and facilities in their research or teaching. Over 11,500 contacts were provided by the ESF. The questionnaire consisted mainly of closed questions with simple rating scales and pre-coded choices or options from which to select. However, some open questions were also included to give respondents sufficient opportunity to present their views fully and freely, and to obtain more detailed qualitative opinions on important issues. Each participant was asked for his/her views on some general or generic issues, as well as on some more specific issues. That is, based on their responses to certain questions, respondents were asked to answer more detailed questions. This can introduce a bias towards people who are interested in the survey or the area, and that should be taken into account when analysing the findings.

The main structure of the survey can be summarised as follows:

- respondent profile including affiliation (place of work), discipline and specific research field;
- current use of network-related tools/services and data networks;
- interaction via different media; geographic requirements for connectivity;
- connection to a National Research and Education Network and to GÉANT2;
- mid-term expectations and developments in network-related services;
- needs, including assessment of the network infrastructure, high-speed connectivity, Grids, Virtual Organisations, large computing and storage facilities, and lightpaths.

Numbers of respondents per country are given in Figure 2.1. The figure shows the widespread origins of participants within Europe. In this respect, the participation from Romania should be looked at cautiously. Due to a technical mistake, Technopolis allowed Romanian researchers to give their colleagues access to the survey without any solicitation, thereby creating an over-representation of this country by a factor of two compared to other countries of similar size. Because of the limited impact on the final results, it was decided to keep the survey as is. One should note that the ratio between the number of respondents and the population of the corresponding country is approximately constant across European countries. This fact and the total number of respondents give a good level of robustness to the survey results.

A very high response rate was achieved, and the number of participants surpassed by far the anticipated level of response. Responses were obtained from 4,392 researchers and academic teachers from across Europe, representing a response rate of 39% of the initial list. The vast majority (68%) of respondents were affiliated to a university or an institute for higher education. A further quarter (27%) was affiliated to research institutions, the vast majority of which were solely publicly funded. The respondents were reasonably evenly spread between the ten broad scientific disciplines mentioned in the questionnaire, with respondents in each discipline accounting for between 4% (in materials science and mechanical engineering) and 18% (in social sciences) of the total.

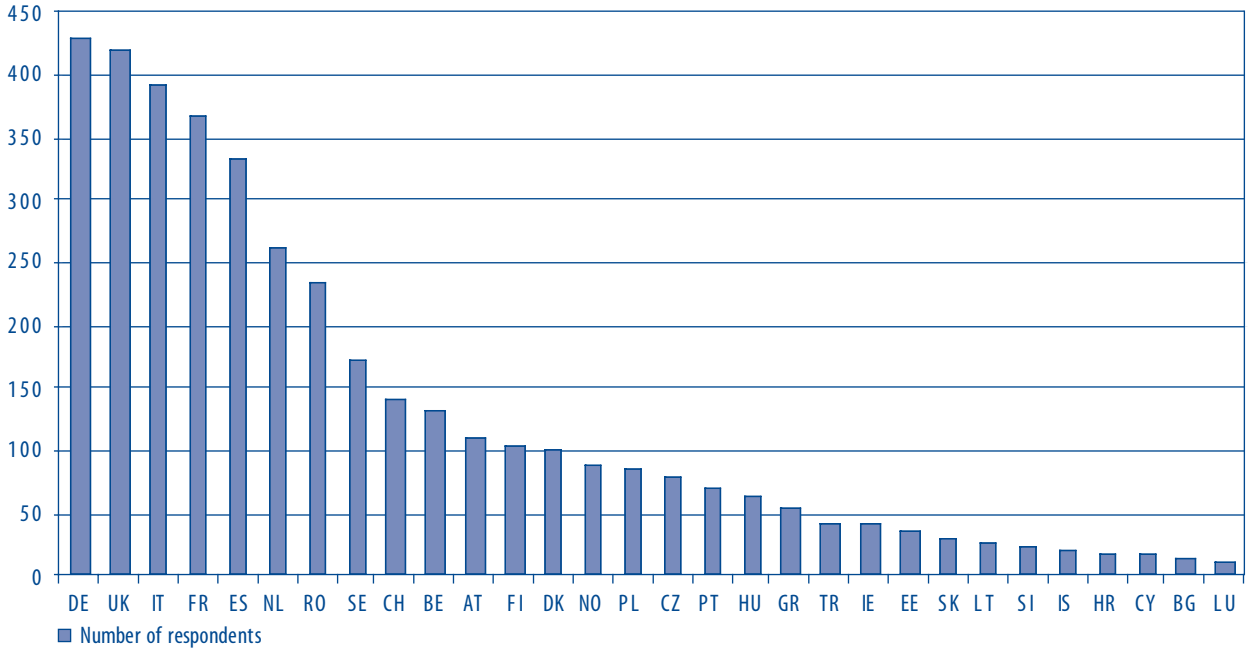

Figure 2.1: Number of respondents per country

Research area	Proportion
Social sciences	18%
Physics and related sciences	17%
Life sciences (incl. biology, biotechnology, . . .)	16%
Environmental sciences (incl. earth sciences, marine sciences)	14%
Humanities	9%
Medical sciences	6%
Chemistry and chemical engineering	6%
Mathematical sciences	6%
IT and computer science	5%
Materials science and mechanical engineering	4%

Table 2.1: Responses per scientific discipline as percentage of total number of responses

2.3.3 The interview stage

The second stage was an 'in-depth' investigation on a smaller scale that was more focused than stage 1. It was conducted immediately after the first stage. Potential interviewees were drawn from the initial total pool based on their expertise, responses in stage 1 and willingness to participate in stage 2. The main goal of the survey in this second stage was to examine and study more thoroughly issues related to access to applications, information, training and IT support. The impact of new network-related services on research and training was also addressed. Finally, the survey focused also on new ideas for the use of data networks in the coming decade. The survey in the second stage has been used to refine, illustrate and confirm the outcomes of the large-scale survey.

The issues examined in the interviews were broadly as follows:

- access to applications and tools (digital libraries, e-learning tools, videoconferencing);
- access to information, training and IT support;
- impact of changes and network-related developments on research;
- limitations as a result of network services or associated services;
- suggested new ideas for the use of data networks in five years' time.

The basic profile of the respondents in the second stage remained close to that of the respondents of the large-scale survey.

3. Network-related services and tools

The Internet originated from networks serving research institutions and universities. It has often been described as a network of networks. Today, the networks that provide connectivity and services to users in research establishments and institutions for higher education are still the most advanced parts of the entire Internet. These networks - commonly referred to as 'research networks' - offer very large network capacities and various advanced services that are not available generally. Many of the technologies and services that are developed and tested in the research-networking environment later find their way to the general Internet, which serves companies as well as individuals who use the Internet for business and leisure. The World Wide Web is no doubt the largest and most prominent historical example, but many more technologies and services have crossed over from the research and higher-education network environment to the rest of the Internet, and this transfer of innovation is continuing and increasing today. It is therefore crucial to study and understand trends in the current use of network-related tools and services in order to foresee future developments and needs in the research community.

3.1 Current use of network-related tools

Respondents were asked how much of their time each day they spent actively using data networks for their research or teaching. Three-quarters (73%) of those who responded indicated that they spent less than two hours using data networks, with over half of these people using networks for less than an hour per day. In comparison, only 10% of respondents reported spending the majority of a working day (four hours or more) actively using data networks. Figure 3.1 shows the spread of responses.

The size of use of data networks is not uniform across scientific disciplines. The disciplines can be divided into three groups, as follows:

- light network users: environmental, mathematical and social sciences[4];
- moderate network users: humanities, life and medical sciences;
- heavy network users: physics and related sciences, materials science and mechanical engineering, IT and computer science, chemistry and chemical engineering [5].

Survey participants were given a list of thirteen network-related tools and were asked which they used and which they expected to use within the coming years. Those currently using any of the tools listed were asked how frequently they used them (daily, weekly, or less often).

The use of many network-related tools has become commonplace among European scientists. The most commonly used tool (used by all but eight respondents) was person-to-person email. Nearly all respondents (more than nine out of ten) also reported using email discussion or distribution lists and transferring large files. The use of a further four tools (wireless access at other institutions or at the respondent's own place of work, wikis and instant messaging) was also widespread, each being used by more than half of the respondents. However, there are some tools that respondents appear to use less widely and/or less frequently, especially IPv6 and bandwidth reservation; both of these are used only by approximately one out of ten respondents.

4. *i.e., an above-average proportion of respondents is spending less than one hour per day*

5. *i.e., an above-average proportion of respondents is spending four hours per day or more*

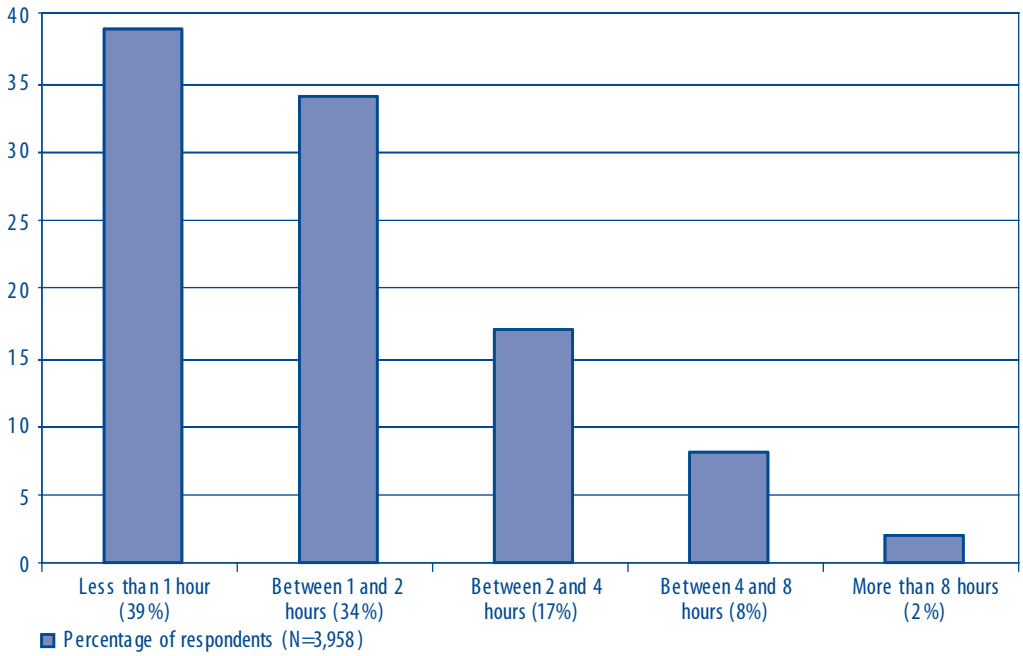

Figure 3.1: Time spent each day actively using networks for research or teaching

Although a tool may be widely used, that does not necessarily mean that it is used very intensively (i.e., on a daily or weekly basis). For example, 61% of respondents use wikis, but half of these users do so less often than once a week. On the other hand, other tools such as Virtual Private Networks are used by relatively few respondents (33%), but are used intensively by those people, with over two-thirds (68%) using a VPN at least every week.

Table 3.1 summarises these two aspects by segmenting the thirteen tools according to how commonly and how frequently they are used.

	Frequently used (daily, weekly)	**Infrequently used (less often)**
Used by the majority	Person-to-person email Email discussion/distribution lists Instant messaging Wireless access at place of work Transfer of large files	Wikis Wireless access at other institutions
Used by the minority	VPNs (Virtual Private Networks)	IP telephony Videoconferencing Bandwidth reservation Encryption of data IPv6

Table 3.1: Tools: use and intensity of use

While the average respondent used just over half (6.7) of the tools listed[6], the number used by an individual respondent varies greatly. One quarter of respondents (24%) reported using fewer than five tools, while a similar number of respondents reported using nine or more. Those using few tools tended to use person-to-person email, email discussion/distribution lists and transfer of large files.

6. *Based on 1,686 respondents who indicated for all tools whether or not they used them*

Use of VPNs and bandwidth reservation were the least commonly used amongst this group. Even among the 'heavy' users (using nine or more tools) these two tools are still the least frequent.

It is important to note that a significant number of respondents did not reply to the question on tools or replied 'don't know'. They were removed from the analysis above. In an extreme example, almost a third (29%) of all respondents gave 'don't know' answers to the question about their use of bandwidth reservation, suggesting a low level of knowledge of its existence, possibly even among those who are in fact using bandwidth reservation. Lack of knowledge and awareness of some of the other tools covered by the survey also appears to be high, such as Virtual Private Networks (16%), wikis (14%) or encryption of data (13%).

Survey responses suggest that the use of all of the tools covered is predicted to increase over the next few years. In the case of more than half of the tools listed, at least one in five of those not currently using them expect to do so within the coming years. If the predictions are correct, then the extent of use of certain tools will change in a particularly dramatic way. The use of IPv6, for example, is expected to almost double (a growth of 92%) from current levels, while videoconferencing (a growth of 53%) and bandwidth reservation (a growth of 45%) are also expected to see large increases in use, although in each of these cases there is a relatively low current level of use as a starting point.

3.2 Current use of network-related services

Survey participants were also asked about their use of seven network-related services. The survey responses suggest a wide spread in the level of use of different services. Digital libraries (97%) and remote databases (93%) were used by nearly all of the respondents (excluding those who did not know or did not reply to the question), while roughly half of the respondents reported using high-resolution visualisation of data, e-learning services for teaching activities, and large computing facilities. In comparison, the least commonly used services - remote control of scientific facilities and computing Grids - were reportedly used by a fairly high 36% and 25% of respondents, respectively.

The spread and intensity of use of different services is summarised through four-way segmentation in Table 3.2. In most cases, the intensity of use reflects how commonly a service is used, i.e., accessing digital libraries and remote databases is done regularly and by a large proportion of users, while other services are used infrequently and by a minority of users. The one exception to this pattern is high-resolution visualisation of data, which is a service being used by more than half of respondents (57%), while the majority of these users (53%) use it less than once a week.

	Frequently used (daily, weekly)	Infrequently used (less often)
Used by the majority	Access to digital libraries Access to remote databases	High-resolution visualisation of data
Used by the minority		Large computing facilities Computing Grids E-learning services for teaching activities Remote control of scientific instruments

Table 3.2: Services: use and intensity of use

While the average respondent uses just over half (i.e., four) of the seven services listed[7], the number used by individuals varies greatly. Of those who indicated for all seven services whether they used

7. *Based on 3,288 respondents who indicated for all services whether or not they used them*

them or not, one in five (19%) made use of fewer than three, while the same number used six or seven. In the majority of cases, 'light' users (those using just one or two of the services) accessed remote databases (75%), while the other services were much less commonly used (by less than 7% each).

A significant number of respondents gave no response to the question on services or replied with 'don't know'. They were not included in the analysis. In the most extreme case, more than one in ten (12%) of all respondents answered 'don't know' about their use of computing Grids. A 'don't know' answer may mean that the respondent uses the service but is unaware of it. It may be that the respondent is unaware of the service because he/she does not use it, or he/she may just be unable to say how often he/she uses the service on average. Therefore it is difficult to draw any firm conclusions from such responses. However, it seems reasonable to assume that the majority of these respondents were people who were not using a service and were not aware of its existence, or who simply were not fully aware of the service. While the knowledge of services in general appears to be much higher than the knowledge of the tools mentioned in the previous section, for each of the services there is still a significant minority that replied 'don't know' to the question about use of that service: computing Grids (12%), high-resolution visualisation of data (5%), remote control of scientific instruments (5%), large computing facilities (3%), e-learning services for teaching (3%), access to remote databases (1%).

As with network-related tools, researchers overwhelmingly predict the use of all network services to increase over the coming years. For example, over one third (36%) of those currently not accessing digital libraries expect to do so in the coming years. If the predictions are correct, then the extent of use of certain services will change in a particularly dramatic way. For example, the use of computing Grids is expected to increase by almost half compared to current levels (a growth of 43%). The use of e-learning services is also expected to see a large increase compared to their current level (a growth of 26%).

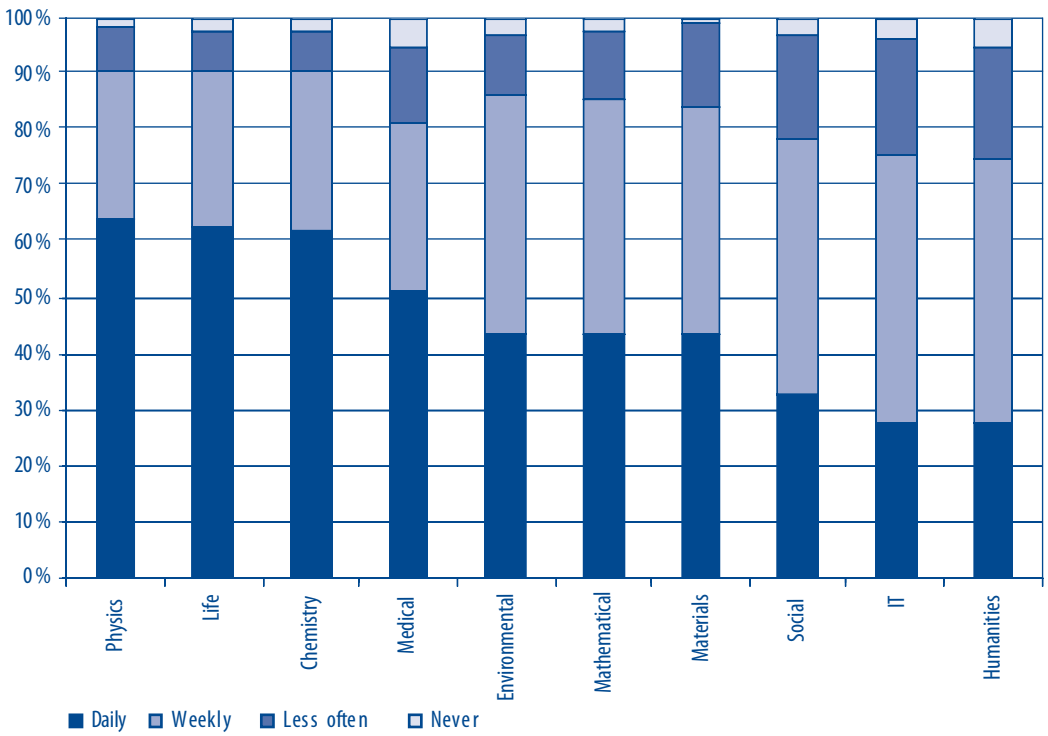

Figure 3.2: Access to digital libraries

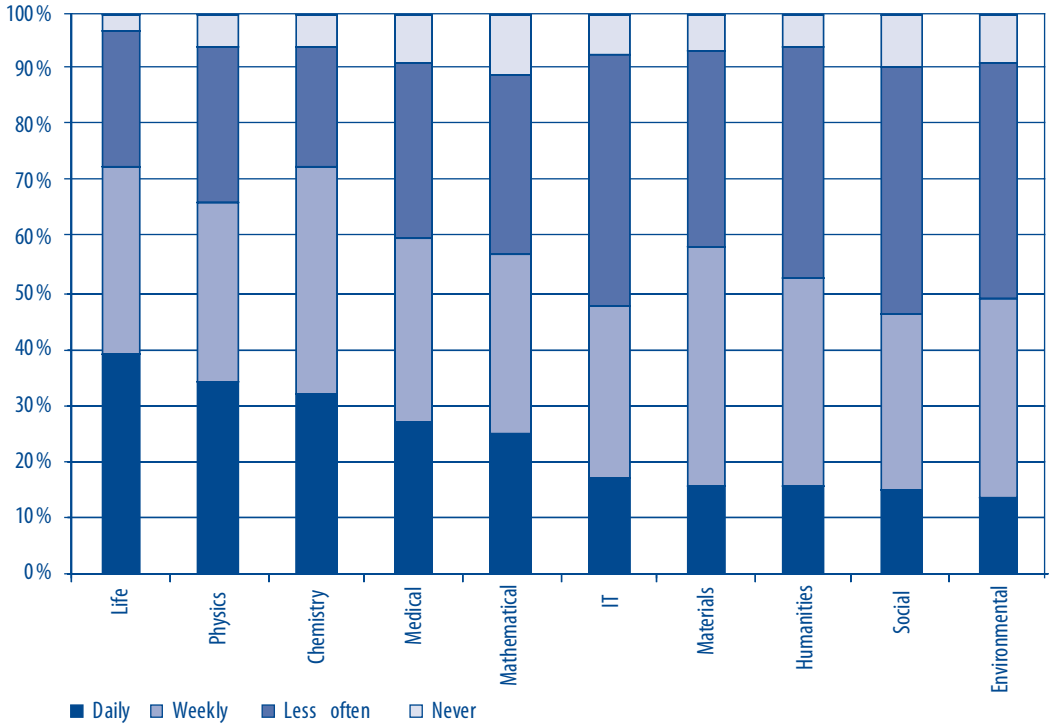

Figure 3.3: Access to remote databases

Stage 1 revealed a widespread and regular use of digital libraries among respondents. Nearly all (97%) accessed digital libraries for their research or teaching activities, with around half (47%) doing so on a daily basis. Moreover, as mentioned above, more than one third (36%) of those not using digital libraries expect to do so within the coming years. The survey in the second stage consulted a range of respondents, from those who access digital libraries on a daily or weekly basis, to those who access them less often. Table 3.3 shows the distribution of how often respondents of stage 1 use digital libraries; the results from stage 2 are very similar.

Daily	Weekly	Less often	Not yet, but within 2-3 years	Never
47%	37%	13%	1%	2%

Table 3.3: How often do you use access to digital libraries for your research or teaching activities?

Researchers currently accessing digital libraries were asked in stage 2 which libraries they used and how important these were for their work. Digital libraries were found to be accessed for a wide variety of services, including the following main areas:

- literature searches of journals, magazines, e-books;
- viewing catalogues and ordering books;
- accessing conference proceedings;
- accessing software toolboxes;
- receiving email alerts from journals;
- accessing databases and digital archives of data.

The survey in stage 1 found that the majority (52%) of respondents were not currently using e-learning services, although one quarter of these respondents expected to do so within the coming few years. Of the researchers currently using e-learning services, more than half (61%) do so less than once a week.

Daily	Weekly	Less often	Not yet, but within 2-3 years	Never
5%	14%	30%	13%	39%

Table 3.4: How often do you use e-learning services for your teaching activities?

3.3 Impact on research

Survey respondents were asked how in their opinion a number of areas had been affected by developments in network-related services over the last decade.

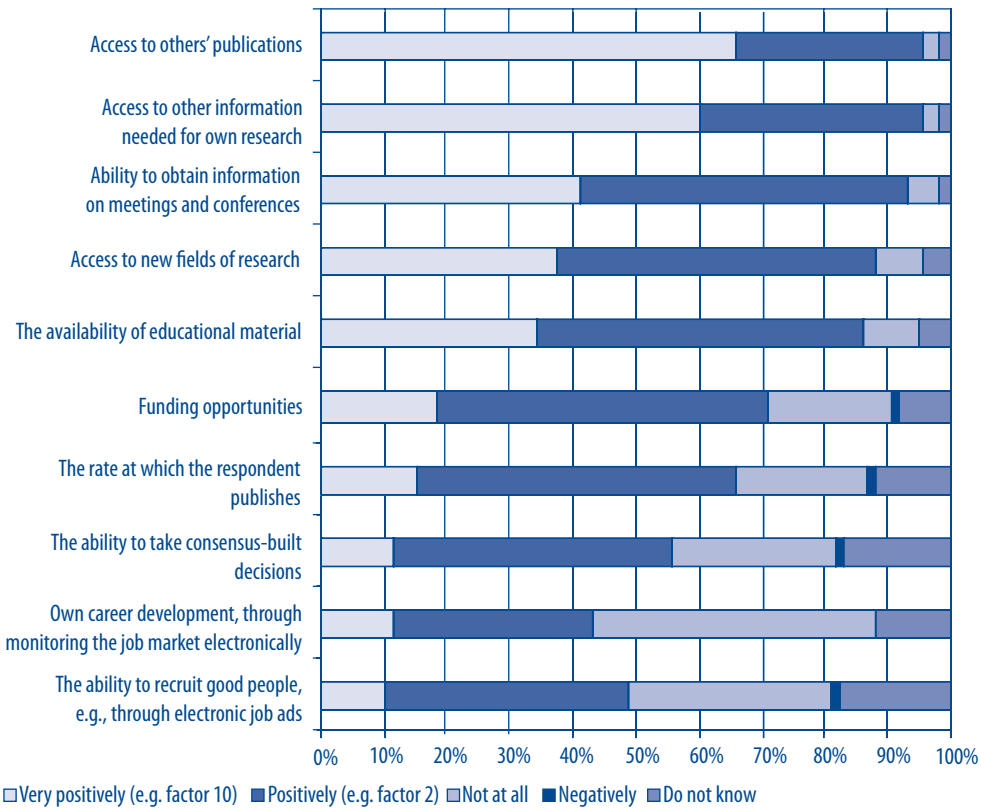

Figure 3.4: Impact on research

Overall, opinions were very positive. For each of the areas, only 1% of respondents or less reported that network-related developments over the last decade had had a negative impact. In fact, in all but one of the areas, the majority of responses claimed 'positive' or 'very positive' effects. The one

exception was the effect on 'your own career development through monitoring the job market electronically,' where a majority of respondents stated that it had not been affected at all by network developments. This may reflect an ignorance or indifference of some respondents to the personal benefits that may be obtained from online job services (e.g., they might not be monitoring the job market at all) rather than indicating that network developments actually do have a merely neutral effect on the monitoring of the job market.

Where respondents reported a 'negative' or 'very positive' effect, they were asked to provide an example of a service where this has been the case and to explain how the development had changed their work. Each of the areas put to respondents is considered separately below, and the main points coming out of the responses to the open question have been summarised.

Negatively	Not at all	Positively (x2)	Very positively (x10)	Total	Don't know / no response
<1%	2%	31%	67%	3,927	465

Table 3.5: Impact on access to others' publications

More than 200 comments related to the very positive effects of network services in searching for, accessing and retrieving publications. Generally, the comments referred to the increase in speed and ease with which published, unpublished or archived publications could now be accessed. Online search facilities were felt to have dramatically reduced the time needed for research, having *"increased the possibility of finding what you are looking for in a huge number of sources in a very short time"*. Respondents most commonly cited Google searches and the use of scientific search engines (such as the Web of Science) as good examples.

Not having to travel or find time to use a physical library was also a commonly highlighted positive development. For example, one respondent pointed to the fact that *"electronic libraries accessible at the office, at home, or virtually any place make writing much easier than before"*. As well as saving time and effort, developments have allowed access to others' publications while travelling, at conferences or from any workplace. A number of examples of remote accessibility were given, including *"I am based at a marine laboratory in a fairly remote location in the Scottish Highlands, but have seen increasing access to online resources, particularly online editions of journals"*.

Negatively	Not at all	Positively (x2)	Very positively (x10)	Total	Don't know / no response
<1%	2%	36%	62%	3,893	499

Table 3.6: Impact on access to other information needed for own research

Developments in network services were generally reported to have resulted in easier access to the work and activities of other research groups and to related information such as guides, results and general information on organisations. Email and the Internet were felt to have *"simply multiplied transfer of information many times"* and speeded up the whole process of research.

For many, accessing bibliographical databases and resources online has been a crucial development. One commentator pointed to a particularly good example: *"In the Netherlands the academic library database and ordering system 'Picata' is a researcher's dream and has made bibliographic work incredibly fast, easy and comprehensive – I often go here to do my research, as this facility is not available in Britain"*.

Negatively	Not at all	Positively (x2)	Very positively (x10)	Total	Don't know / no response
<1%	8%	53%	39%	3,840	552

Table 3.7: Impact on access to new fields of research

Many comments from respondents related to the increase in recent years in their ability to keep up to date with the latest developments and research in their field. However, a number of the responses also highlighted how easy it had become to start looking into other fields and enhancing the interdisciplinary nature of research. For example, one respondent commented that, *"access to publications, especially in related fields, but in journals not normally accessible in our library, has very considerably broadened our horizons and therefore influenced our research".* Another related example was that *"computational linguistics is on the edge of a number of fields and a fast access to any, even remotely related, field or paper is crucial for building a well-informed overview"*.

Negatively	Not at all	Positively (x2)	Very positively (x10)	Total	Don't know / no response
<1%	9%	55%	35%	3,809	583

Table 3.8: Impact on the availability of educational material

A number of examples were provided to show how network developments had increased or improved the availability of educational material. The main common themes are covered by the following comments:

- *"Education material is widely available for teaching, which supplements my own material greatly";*
- *"The possibility of finding photos, pictures and other educational materials (e.g., software packages with free student licences) to improve course materials is very positive";*
- *"I often use material found on the Internet in my courses, e.g., newspaper articles, statistical data, opinion statements".*

Negatively	Not at all	Positively (x2)	Very positively (x10)	Total	Don't know / no response
1%	22%	57%	20%	3,668	724

Table 3.9: Impact on funding opportunities

Positive comments regarding the effects of service developments on funding opportunities were not very detailed, but clearly showed the importance of websites, Internet searches and email distribution lists in providing information and access to such opportunities. As a result of these developments, the potential for large-scale international opportunities was also felt to have increased. The electronic submission of applications was commented on by some to be more fast and efficient, with one respondent stating *"it is easy to 'recycle' applications across different funding agencies"*.

Negatively	Not at all	Positively (x2)	Very positively (x10)	Total	Don't know / no response
1%	24%	58%	17%	3,523	869

Table 3.10: Impact on the rate at which the respondent publishes

Many of the positive comments related to improvements in the submission and editorial processes. Electronic submission of manuscripts to publications is seen by many to be a key factor accelerating

publication speeds over the last decade. But the wider editorial process was also felt to have improved as a result of network developments. For example, *"editors can send me a review electronically and articles are easily improved through email discussions with editors, making the publication process more efficient".* An improved ability to communicate internationally has also helped to accelerate collaborative publication rates, with *"fast exchange of ideas and manuscript drafts between collaborating researchers by email"*. One respondent also highlighted the fact that the Internet has *"created a greater variety of publication venues for conference papers, working papers etc."*.

Negatively	Not at all	Positively (x2)	Very positively (x10)	Total	Don't know / no response
1%	32%	54%	14%	3,317	1,075

Table 3.11: Impact on the ability to take consensus-built decisions

A number of examples were provided of how consensus-built decisions can be made largely or solely through network tools and services as a result of developments in recent years. A selection of these comments is provided below as examples:

- *"I undertake project planning by email circulation";*
- *"I organise videoconference meetings for my EU and national projects. Email messages have legal status; therefore decisions by committees have been taken simply by email rounds";*
- *"The co-ordination of an FP5 research project with ten partners - it would have been impossible to write the proposal and to run the project without intensive use of network-related services";*
- *"I am a member of the executive board meeting at the European Association of Archaeologists. All problems are discussed / all decisions are made through email forums".*

3.4 Needs and expectations

Respondents were asked how they expected a number of areas to develop over the next decade. The results, which are summarised in Figure 3.5, were generally positive, with the majority of respondents expecting a slight or significant increase in each of the areas covered. A significant increase was most commonly expected in the extent to which collaboration would take place with other researchers abroad. More than 82% of respondents felt that this would increase slightly or significantly over the next decade. Some two thirds expected increases in large collaborative project work, collaboration with domestic researchers, and digital communications replacing travel. However, around one third of the respondents remained more sceptical (no answer, 'don't know' or 'not applicable' (N/A) answers) about how the extent of teleworking and the extent of distant teaching will develop in the years to come.

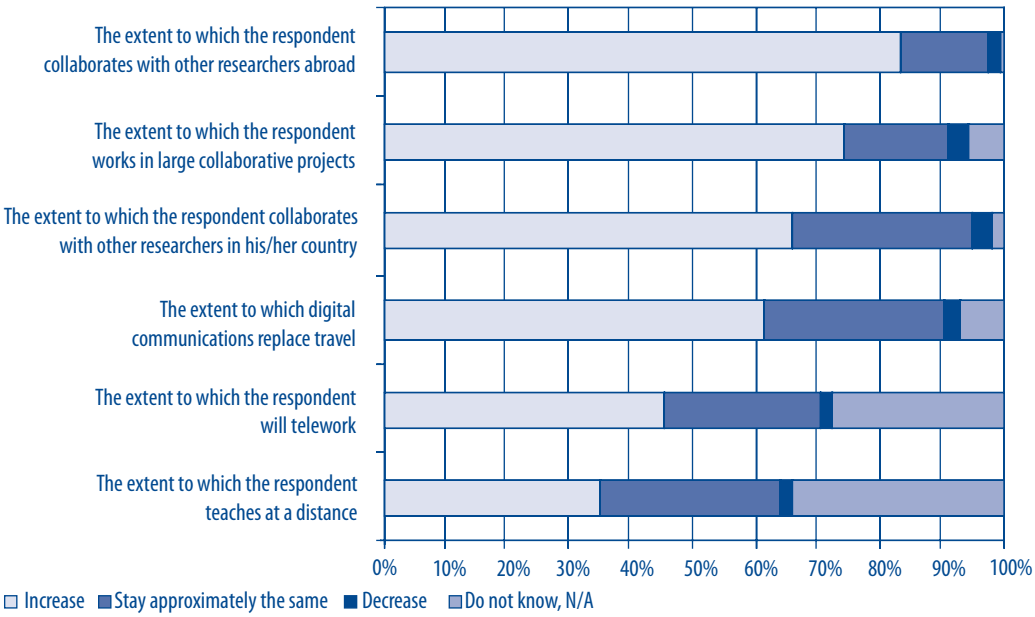

Figure 3.5: Expected development over the next decade

Respondents were also asked what they would like to do five years from now, using data networks for their research or teaching, that they were not doing at present, regardless of technical or financial feasibility. Over 1,800 separate comments were received. While it is not possible to present all of these responses in this report, or to summarise all of the points made, a selection of the more detailed comments is given below, relating to areas that were addressed most commonly throughout the responses:

- *"I would need a robust, well-supported, high-bandwidth network infrastructure, which can easily be accessed from almost anywhere in the world, including rural areas. Unfortunately, current prices prevent satellite-based access from being economical. I hope for a time when Internet access of ~5 Mb/s is basically available everywhere. That would significantly improve my mode of research (I am travelling a lot and I am often impeded by having to work in locations where above-minimum services are not available)."*
- *"Computer centres that not only have large supercomputers, but also smaller state-of-the-art workstations. Computer time at the workstations should be easy to get (a certain amount of money could be paid by the university / funding organisation for a certain CPU time). All possible compilers, libraries and scientific software are already installed. You can install your own software without any administration."*
- *"To make maximum use of technologies to work with others at a remote distance, within the country and internationally, in the same way that I can work with people in the office next-door. I would also like to make maximum use of teaching technologies to deliver different kinds of material, interact with students at different levels than is currently possible, and achieve their engagement in ways that stimulate them and allow them to make better connections with the work environment."*
- *"Read books on line. For most disciplines in the humanities, the 'great leap forward' would be access to digital books. The book was and continues to be for many disciplines the central publication medium."*
- *"The scientific contribution in Europe is from many languages. It is always easier to look for a paper*

in your mother tongue than in English. I hope that we can build a European database for all scientific contributions in which any paper should be translated in all European languages (at least the abstract and title) so that anyone can find what he is looking for in his mother tongue. This translation could be done by software maybe."

- *"Communication is the cornerstone of teaching and learning. I expect new networks to foster this."*
- *"I would like to see mini-conferencing over networks taking over from an excess of international conferences requiring one's physical presence, i.e., shorter meetings of specialists to exchange ideas, results, etc. and to obtain feedback."*
- *"Work on large-scale databases compiled by multiple researchers, with advanced tools for finding discrepancies or duplication of data."*
- *"I would like to have an identical, integrated working environment at work, at home or travelling. I expect mobile access to electronic media to become as cheap as the network at work. I hope that a universal authentication scheme (using possession, property, and secret) will regulate access to all electronic resources."*
- *"Much of the data that is generated in my field is not available on the Web. Instead it is 'hidden' in publications etc. and hence it is difficult to compare the results from different studies. Another area is calculations, which are also not widely available over the Web. It would be great if a database was created to assemble the data and calculations that have been generated over the last few years."*
- *"Our 'virtual organisation' is essential for all aspects of research in our community of computational science, and by far the biggest problem is that funding agencies, including ESF, do not recognise it as an essential infrastructure. So we have a big problem maintaining it."*

In summary, according to respondents, it appears that there is a need for standardisation of network-related services, as well as a correct security level. This goes in parallel with an effort towards more user-friendly services and towards a better and more extended awareness of the existing services.

3.5 Limitations

Survey respondents were also asked if they experienced limitations on their research as a result of the network or associated services. In general, the severity of the limitations was assessed to be low. The main limitations were:

- increased workload / too much information / less time for research;
- the network being slow, regularly crashing or being down for long periods;
- issues around spam filters and firewalls;
- limited bandwidth and storage;
- limited local support and hardware (e.g., the network is sufficient but there is only poor (sub-optimal) technical support and/or limited equipment for videoconferencing available).

4. Co-operation and communication

4.1 Means of interaction

Respondents were asked to estimate how many hours they spent each week interacting with their peers via different types of media. Overall, respondents spent an average of 15 hours interacting with other researchers via all forms of media combined. However, some 3% reported spending more than 40 hours each week. Table 4.1 summarises the results for each of the different media. Face-to-face meetings account for the highest number of hours of interaction during a week, averaging some 7 hours. The majority of respondents (61%) spent more than 5 hours each week on face-to-face meetings. Email accounted for a similar amount of time per week, 6.5 hours on average. Telephone calls were the only other sizeable consumer of time, averaging two hours per week, while the remaining methods only accounted for around one hour in total. Remarkably, email was the only medium for interacting with peers that all respondents said they used (0% ticked 0 hours).

	Average (hours)	0 hours	Up to 5 hours	More than 5 hours
Face-to-face meetings	7.2	2%	37%	61%
Email	6.5	0%	44%	55%
Phone	2.0	8%	82%	10%
Postal letters	0.5	47%	52%	1%
Fax	0.2	66%	33%	0%
Videoconferencing	0.2	81%	18%	0%

Table 4.1: Time spent each week interacting with other researchers

A breakdown of the use of different media by scientific discipline showed some variations. It is to be noted in particular that in the mathematical sciences interaction is below average across all six different forms of media. At the other end of the spectrum, researchers in IT and computer science spend more than three times the average amount of time each week doing videoconferencing, although this is still only half an hour per week on average. Responses in other sections suggest that collaboration with overseas researchers is expected to increase significantly in the future, but also that interaction and consensus building through certain media, such as email, have their drawbacks. This may result in an increased use of, or demand for, videoconferencing in the future.

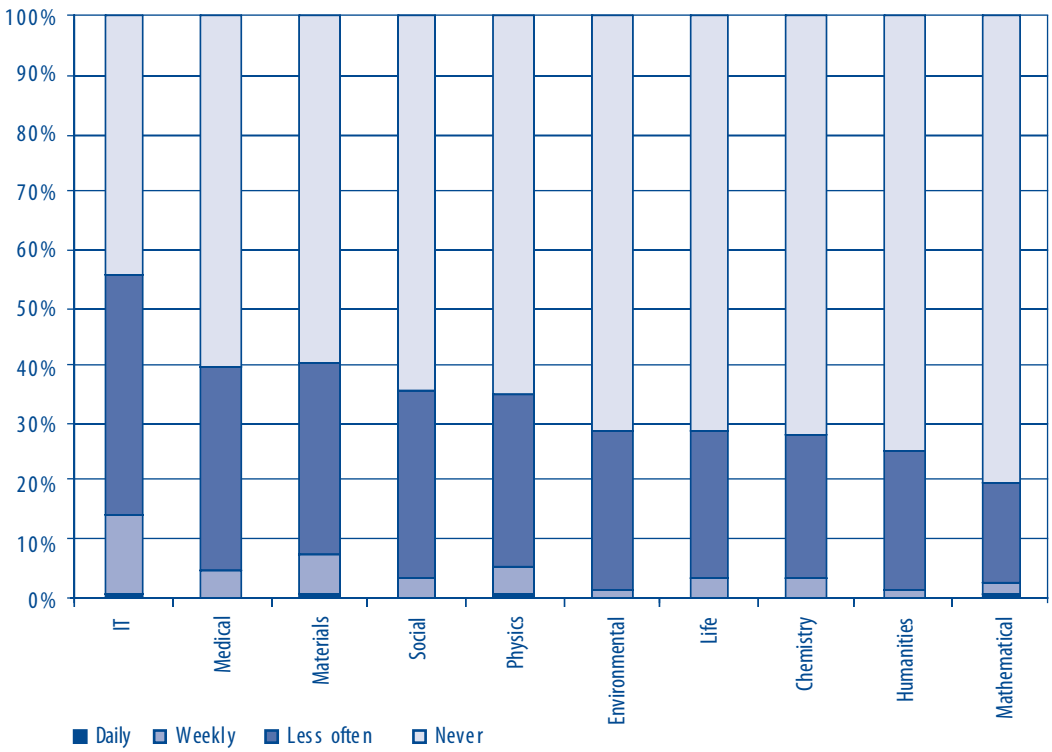

Figure 4.1: Use of videoconferencing

4.2 Needs and expectations

Survey respondents who used videoconferencing explained that this was commonly done to replace regular meetings and reduce travel time, to co-ordinate distributed projects, for teaching and for internal communication across different sites. Those currently not using videoconferencing for their research were asked whether there were any specific reasons why not and which improvements would encourage them to start using it. Approximately one third of the respondents who are not currently using videoconferencing felt that wider availability of facilities and resources would be the improvement that might encourage them to use it. Other individuals suggested that improvements in quality and speed, better training in set-up and operation, and reduced costs would be desirable.

Daily	Weekly	Less often	Not yet, but within 2-3 years	Never
0%	4%	29%	17%	50%

Table 4.2: How often do you use videoconferencing for your research or teaching activities?

Responses to the survey in stage 1 showed that nearly half (47%) of respondents felt that they did not receive adequate training in network use to improve the quality of their research or teaching. The survey in the second stage asked whether respondents benefited from training or IT support to keep them informed about developments in network-related tools and applications. Many respondents

reported receiving no training or IT support at all in this area. Some respondents mentioned that the courses available were too simple for their applications or needs, or that they did not have time to attend the training that was available. In summary, the opinions expressed are a clear indicator that more training, adaptation and simplification of services are needed as well as a broader interdisciplinary approach of existing tools.

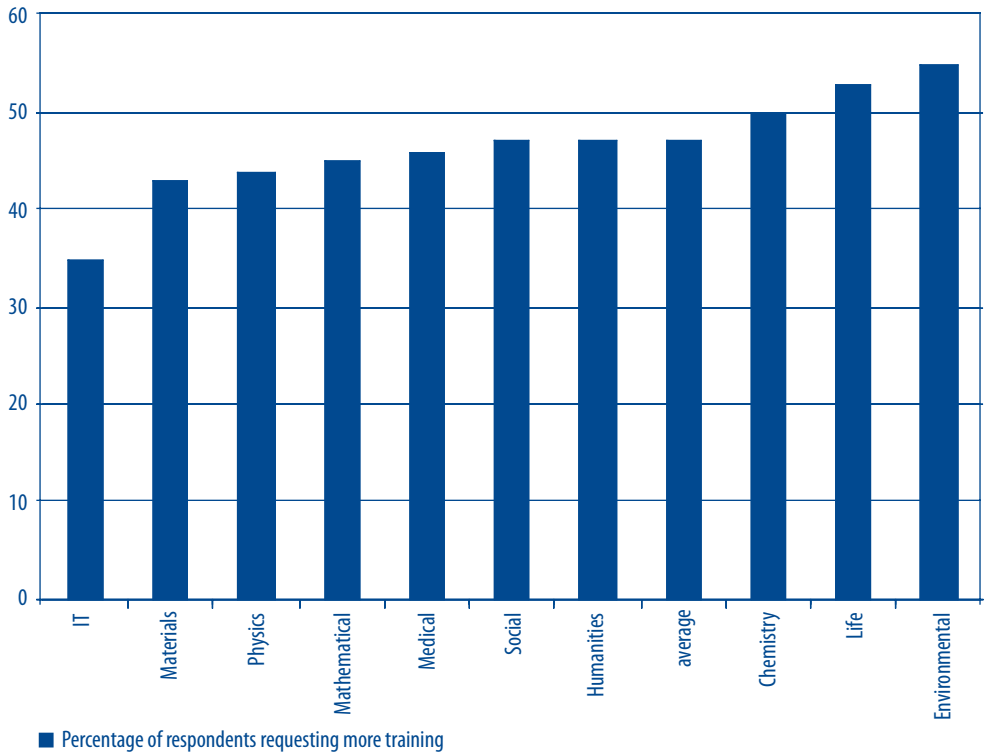

Figure 4.2: Respondents who do not receive adequate training in network use to improve the quality of their research or teaching

5. Capacities and infrastructures

5.1 Use and access

5.1.1 Assessment of the network infrastructure

Respondents were asked to express their degree of satisfaction or dissatisfaction regarding the network infrastructure that they use at their usual workplace.

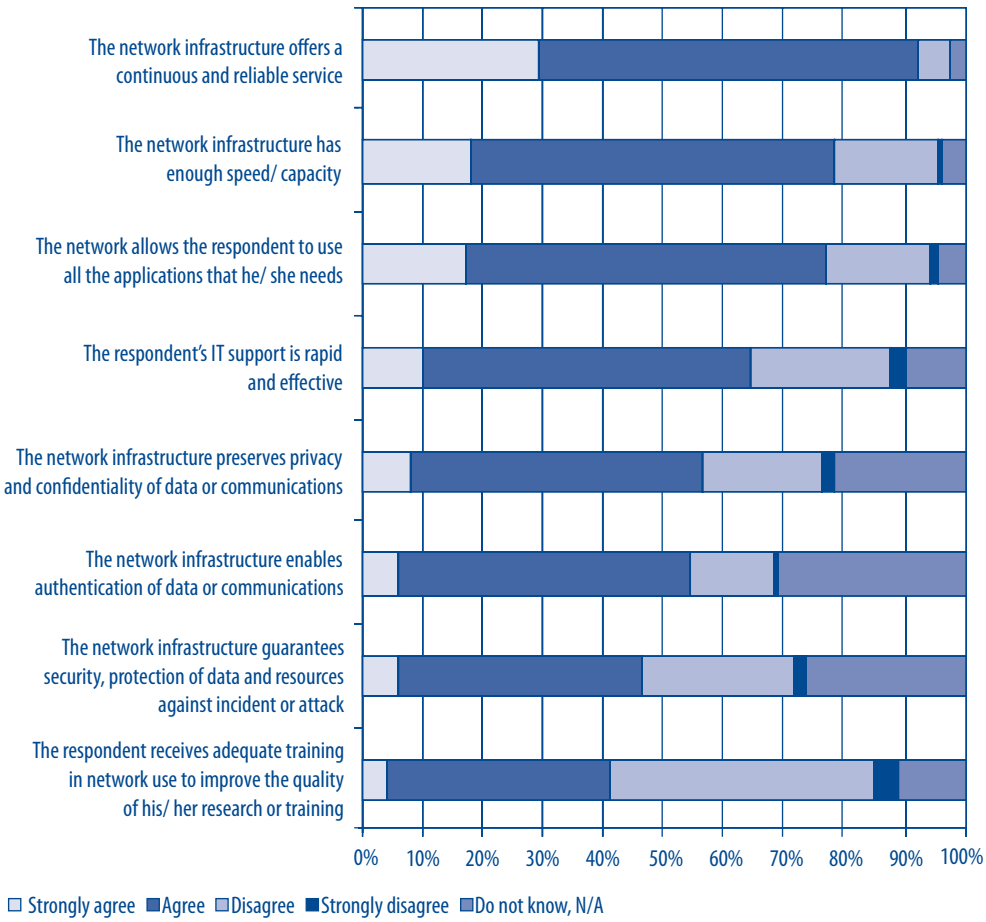

Figure 5.1: Degree of satisfaction with the network infrastructure available at workplace

The network infrastructure at the workplace is perceived as satisfactory by researchers: it offers a continuous and reliable service for more than 90% of respondents, it allows them to use all the applications they need (77%), and the network infrastructure has enough speed/capacity for 78% of respondents. IT support is assessed as rapid and effective by 64% of respondents. The major cause

for dissatisfaction is the lack of adequate training in network use to improve the quality of research or teaching activities, listed by 47% of respondents.

Satisfaction regarding network infrastructure is not uniform across scientific disciplines. Especially, as can be seen from Figure 4.2, researchers in IT and computer sciences are more likely to be satisfied with the training they receive to improve their use of network infrastructures than researchers in other disciplines. By contrast, researchers in environmental sciences and life sciences express a severe lack of training in network use. Life sciences and medical sciences are the disciplines where researchers are the least satisfied with IT support services.

Concerning the preservation of privacy and confidentiality, and especially security guarantees, IT and computer science researchers express a much higher level of dissatisfaction than researchers in other disciplines.

Finally, regarding speed/capacity of the network infrastructure, the largest portion of satisfied researchers is found in the mathematical sciences. The largest portion of dissatisfied researchers is found in chemistry and chemical engineering. Where respondents strongly disagreed with one of the statements about their network infrastructure, they were asked to provide further details. Over 300 responses were received across the different areas. The main themes in each area are summarised below.

The network infrastructure offers a continuous and reliable service

Few comments were made specifically regarding this aspect, although many of the comments made elsewhere were also relevant to this broad area. One respondent reported a decline in the available service in the afternoons and weekends and another commented more generally that their network was often down. Both respondents also remarked on the fact that emails were frequently lost.

The network infrastructure allows me to use all the applications that I need

Nearly twenty comments were given that specifically related to this aspect of the infrastructure. Some felt that the lack of access to necessary applications was entirely dependent on the purchasing of licences by the institution, rather than any issues with the quality of the network. There was also felt to be a need to move from a 'one user – one licence' concept to more open-source applications and operating systems. Comments made elsewhere in the questionnaire would suggest that some users have come to rely on developing their own/home IT facilities to meet their needs because they are dissatisfied with the provision by their network infrastructure.

The network infrastructure has enough speed/capacity

Nearly twenty comments were made specifically relating to this aspect of the network infrastructure. The majority of the commentators gave little information, simply stating that their network was very slow or had a tendency to crash, that there was insufficient storage capacity, badly maintained and ageing computers or systems, and that there was often a need for greater bandwidth. One respondent highlighted that with file sizes doubling every year or two, there was a need for networks to expand regularly if they are to cope with the increased traffic load.

The network infrastructure preserves privacy and confidentiality of data or communications

A number of respondents commented on the fact that privacy on the network or over the Internet, in particular concerning data or communication, is limited, not guaranteed or outright non-existent. It was generally felt that communication via email can be constantly monitored (and is increasingly monitored because of the fear of virus attacks) and that all communication over the network is in principle accessible to outsiders and traceable. Privacy and confidentiality of emails, for example, is *"prevented by the possibility to forward them entirely, or even worse, part of them"*. There is no law that forbids duplication/reading of transferred data between sender and recipient, as with postal laws. However, some respondents made it clear that the extent to which this leads to breaches of privacy is difficult to judge, as they do not have enough information to know if the system is being abused.

The network infrastructure guarantees security, protection of data or resources against accident or attack

Security of data appears to be a common issue of concern with current network infrastructures, although it was common for respondents not to know the extent to which their network truly provided security. Many respondents reported having lost information through damage or attack. Where there are systems in place, such as backup storage, encryption and firewalls, these are not seen as a guarantee of safety and security.

There was felt to be a need for improvements in the provision and use of backup systems to prevent the loss of important data. Some reported having no backup system at all, while others complained that files where not held off-site or that storage sizes were inadequate for modern project needs. Some reported that there was a reliance on the individual to deal with the protection of his/her own data, and that there should be greater and more effective institutional action to cope with the threat of hardware breakdown or attack.

Your IT support is rapid and effective

Nearly 80 comments were received regarding dissatisfaction with the effectiveness and speed of IT support. The majority gave little detail, merely commenting on the fact that their IT support was generally slow, inefficient, unhelpful or not adapted to technical or scientific needs. A number felt that the quality and quantity of IT support to front-line staff had decreased over recent years and sometimes had been overly centralised or replaced by call centres. Many reported having no IT support at all and that there was an increasing reliance on the skills and knowledge of the users to support themselves. Another common problem reported was that IT support was provided for Microsoft users, but that there was little or no support for users of non-Windows platforms such as GNU, Linux or Mac.

You receive adequate training in network use to improve the quality of your research

Nearly 100 comments were received regarding the adequacy of training in network use. Nearly all of these respondents reported having received no formal training at all (whether that be basic initiation training, training on specific programmes or ongoing 'updating' training). The remainder reported that they received very little training or that the level of training provided was not sufficient to stay up to date. Without formal training provision, many have had to rely on their own knowledge and to learn through practice or from younger or more knowledgeable colleagues.

5.1.2 Connection to a National Research and Education Network

Respondents were asked whether the local network at their institution was connected to a National Research and Education Network. Importantly, a significant proportion (43%[8]) of respondents answered 'don't know', suggesting low levels of knowledge and awareness of these national networks generally. Of those who were able to answer, over three quarters (79%) replied in the affirmative, yet only 82% of these people could actually select the name of their national network from a list. Overall, only one third of all who participated in the survey gave the name of the NREN that they thought their institution was connected to. In those cases where the respondents gave their main place of work, it was possible to compare this information with the NREN they selected from the list. This analysis would suggest that only 58 (or 4%) of those who gave the name of their NREN gave one that did not match the country where they work, suggesting that the overall 'knowledge level' of this one third is a true reflection.

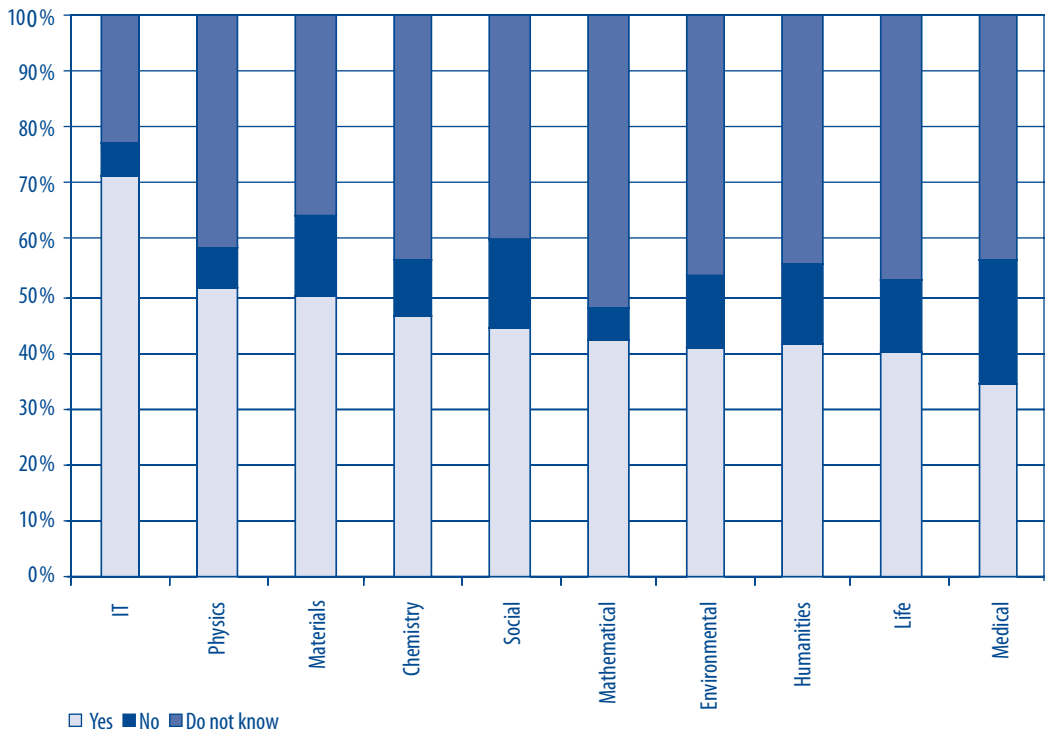

Figure 5.2: Is the local network at your institution connected to a national research and education network?

5.1.3 Connection to GÉANT

As explained in Chapter 2, GÉANT2 is the multi-Gigabit current generation of the pan-European backbone research and education network that connects Europe's NRENs. Survey respondents were asked whether the local network at their institution was (via another network) connected to this GÉANT network. The results suggest that, as with NRENs themselves, levels of knowledge and awareness of GÉANT amongst scientists are low. Roughly 80% of the respondents who knew that their institution was connected to an NREN did not know if that network was connected to GÉANT.

8. *The 13% who did not respond to this question have been excluded from the calculation.*

Overall, only 13% of those who knew they were connected to an NREN also said that they were connected to GÉANT, although as a proportion of all survey participants, this figure falls to 5%.

5.1.4 Computing Grids

Only 232 persons out of 3,787 respondents (6%) are using Grids for their teaching or research activities (see Figure 5.3). More than 70% of respondents do not know about Grids – among them are 1,081 respondents who have heard of Grids but do not know about their use in their area of research or teaching. Another 12.6% of respondents are not using Grids yet, but expect to do so in five years' time.

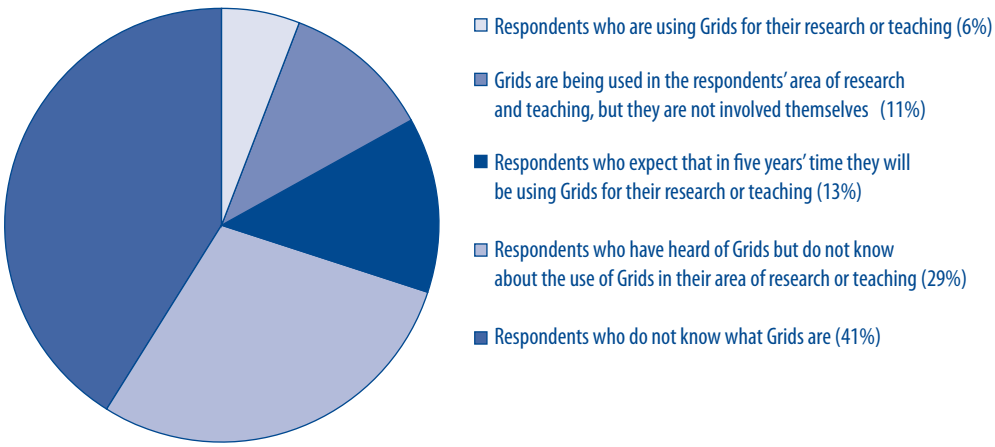

Figure 5.3: Knowledge and use of Grid computing

With regard to knowledge and use of Grids across scientific disciplines, a major finding is that 17% of respondents working in IT and computing science replied that they are using Grids for their research or teaching activity today. According to the responses to this question, Grids are the least known and used among medical-science researchers, social scientists and researchers in the humanities.

Respondents were then asked to provide examples of the main area of application and benefit of Grids. Their contributions fit into two categories: an overall assessment of the benefits of Grids, and specific research fields where Grids are of particular interest. The main benefits of Grids listed are the analysis and sharing of large data sets (incl. literature analysis), computer/numerical simulation, data mining and distributed/parallel computing. Fewer than ten people considered computing Grids to be not useful.

As mentioned in Section 3.2, when asked in an earlier question about how frequently they use network-related services, 25% of respondents answered that they were using computing Grids daily, weekly or less often. (The variation of responses to that question is given in Figure 5.4). Apparently, many respondents who indicated that they use computing Grids, frequently or rarely, do not consider that use relevant enough to state positively that they use Grids for their research or teaching.

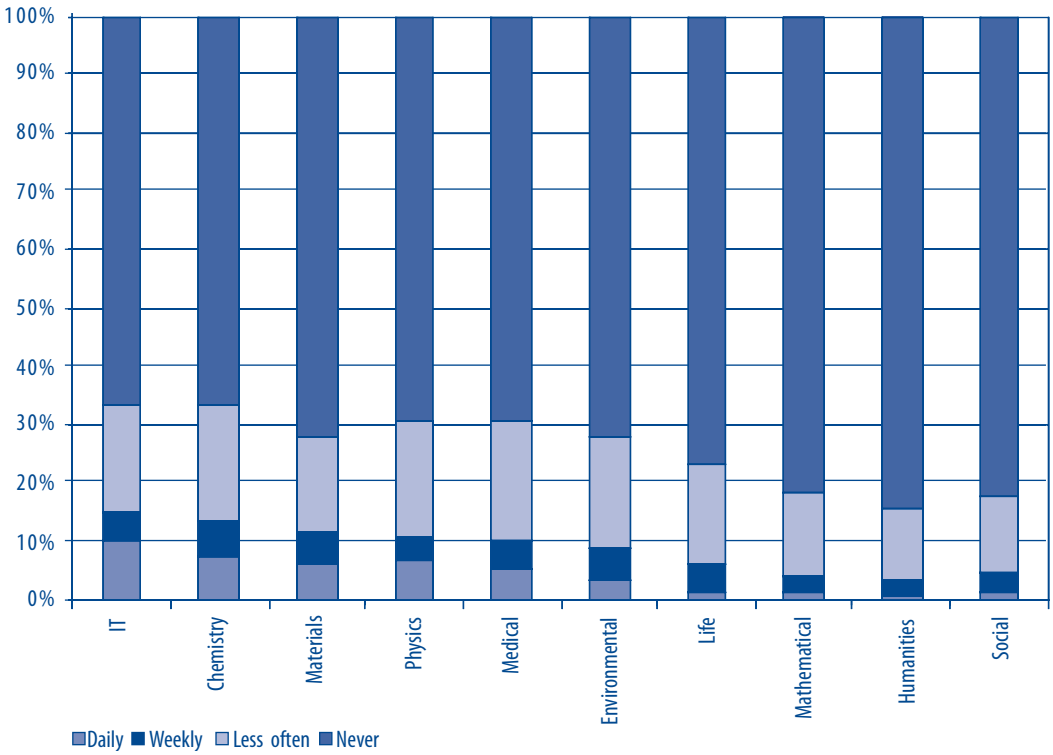

Figure 5.4: Use of computing Grids

5.1.5 Virtual Organisations

Respondents were more familiar with Virtual Organisations than with Grids: 19% (724) of them even stated belonging to one. 21% of respondents expected that in five years' time they will be involved in a Virtual Organisation in their area of research or teaching.

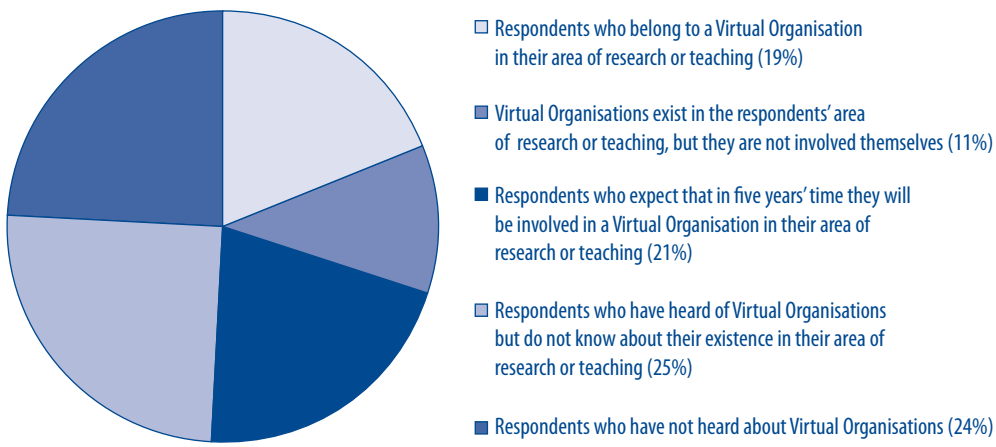

Figure 5.5: Knowledge of, and involvement in, Virtual Organisations

There is little variation in responses across scientific disciplines. The main finding is that 37% of researchers in IT and computing science stated that they already belonged to a Virtual Organisation.

Respondents belonging to a Virtual Organisation expressed their views about the benefits of Virtual Organisations for researchers and academic teachers. The following main advantages can be highlighted:

- easier access to other researchers' work; better sharing of results and know-how (*"creating a global network of specialists"; "reach critical mass"; "to process data and share them with other people processing the data for other aims: it is giving different points of view in the interpretation of data"*);
- extension of collaboration possibilities (incl. building proposals and new research teams);
- cost reduction (e.g., reduced travel costs);
- time saving (*"shortening the time needed to do a collective task just makes it possible"*);
- easier access to, or distribution of, teaching materials (*"pool teaching at Research Master or PhD level among several institutions to offer higher-quality teaching and more diversity for students"*);
- efficiency (*"to settle common outputs and working processes without complex formalised organisational issues"*) and speed;
- flexibility (e.g., *"flexibility to optimise research teams without geographical constraints"*).

5.1.6 Large scientific computing facilities

About 37% of respondents to the survey use large scientific computing facilities or expect to do so within the next decade. Across disciplines, the main users are researchers in physics and related sciences (50%). Only 24% of social scientists and 21% of researchers in the humanities use or expect to use large scientific computing facilities.

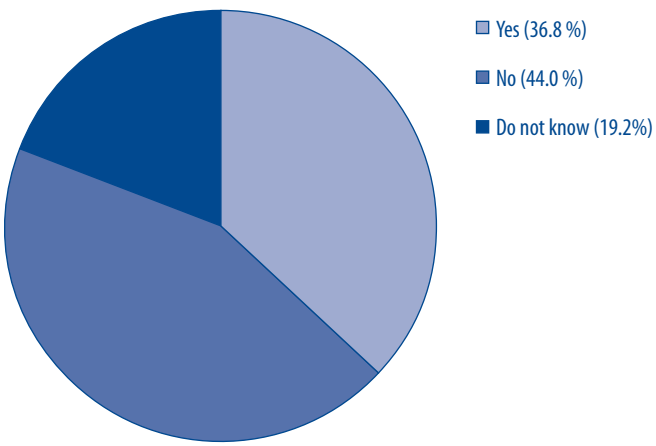

Figure 5.6: Do you use large scientific computing facilities, or expect to do so within the next 5-10 years?

However, the majority (61%) of respondents who use or expect to use large scientific computing facilities do not know the size of the largest computing facility that they can access. The others assessed the size of the largest computing facility that they have access to (see Figure 5.7); for the majority, the largest facility is less than 3 TFlops.

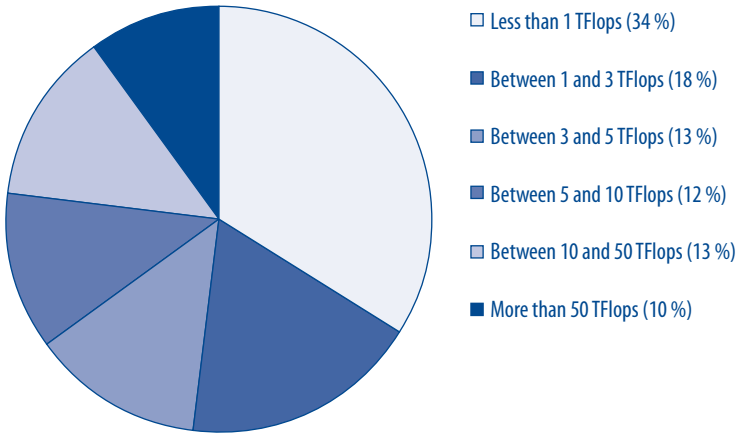

Figure 5.7: Size of largest computing facility that the respondent has access to

Today, the large majority of respondents consider that largest computing facility to be completely adequate to their needs (81% of the 1,118 respondents who felt that they could judge the adequacy). However, 52% of the 852 respondents who felt that they could judge the future adequacy expect that computing facility to be inadequate to their needs in 5-10 years' time. Finally, respondents were asked to describe the largest computing facility that they have access to: it is mostly an institutional infrastructure (64%) or a national infrastructure (26%).

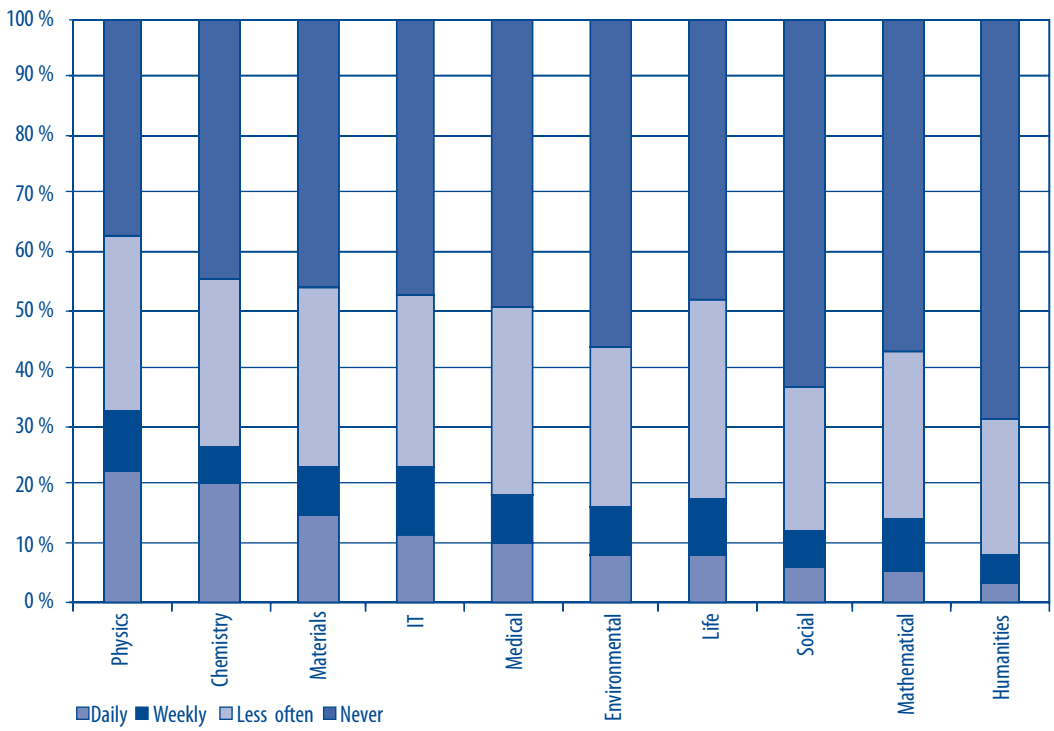

Figure 5.8: Use of large computing facilities

As mentioned in Section 3.2, when asked in an earlier question about their frequency of use of network-related services, a large minority of respondents answered that they were using large computing facilities daily, weekly or less often. The variation of responses to that question is given in Figure 5.8.

5.1.7 Large data storage facilities

Use and knowledge of large data storage facilities are quite similar to the use and knowledge of large scientific computing facilities. Indeed, 39% of respondents to the survey use large storage facilities or expect to do so within the next decade. In the life sciences, 51% of respondents use large storage facilities. At the other end of the spectrum, only 23% of researchers in the mathematical sciences use or expect to use large storage facilities.

A large minority (43%) of respondents who use or expect to use large storage facilities do not know the size of the largest data storage facility that they have access to. The others assessed the size of the largest storage facility that they have access to (see Figure 5.9); for 45% of them, the largest facility is less than 1 TB.

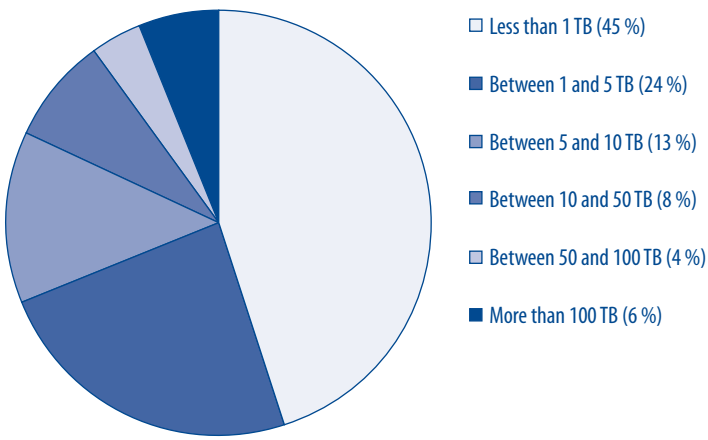

Figure 5.9: Size of largest data storage facility that the respondent has access to

Today, the large majority of respondents consider the largest accessible storage facility to be completely adequate to their needs (84% of the 1,255 respondents who felt that they could judge the adequacy). However, the majority of respondents expect that storage facility to be inadequate to their needs in 5-10 years' time.

5.1.8 Lightpaths

Only 17% of respondents (647 persons) confirm having heard of lightpaths. Of those, only 22% state that lightpaths are already being used in their research area. In addition, 36% of the respondents who have heard about lightpaths expect that lightpaths will be used in their research area within the next five years.

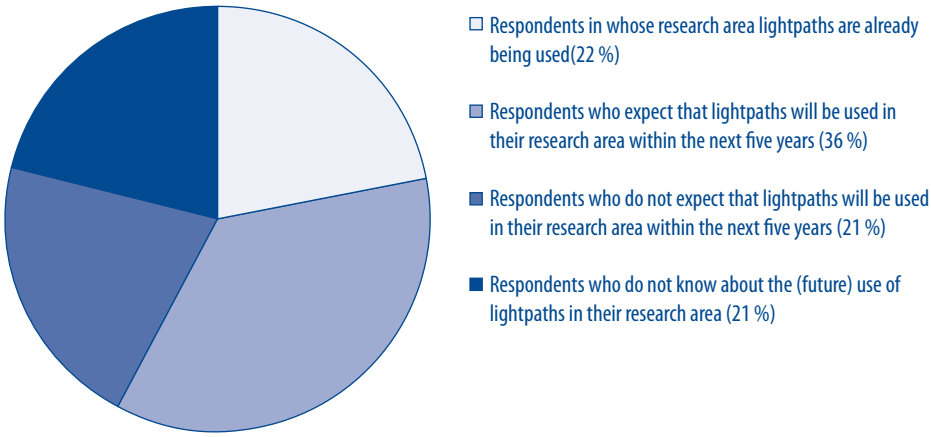

Figure 5.10: Expectations about the use of lightpaths in the respondents' research area

5.2 Needs and expectations

As detailed in the previous sections, most respondents expected the extent to which they collaborate with researchers outside their own country to increase over the next 5-10 years as a result of IT and Grid technologies. Understanding the importance and pattern of international collaboration is important for decisions affecting the future development of international connectivity. Respondents were asked to select up to five regions of the world to which they most required reliable high-speed network connectivity for their work.

The four regions of Europe (western, central, southern and eastern) all appeared in the top 5 choices overall, with western Europe being significantly more popular (selected by 74% of respondents) than the others[9]. This result is in part due to the fact that the majority of respondents are working in western Europe or in neighbouring countries. However, it is noteworthy that respondents in eastern and southern Europe selected/prioritised western Europe (76% and 70% respectively) more often than their own region (39% and 57%). This happens to coincide with the perceptions about where the best research jobs in Europe are and the intra-European brain drain vector, i.e., European scientists seek positions preferably in western Europe. Likewise conspicuous is that the United States and Canada also rank highly in second place overall, selected by 64% of respondents. This region was particularly popular/important for researchers in northern and western Europe. Australia and New Zealand were also important for researchers in northern and western Europe (especially in the United Kingdom), but to a lesser degree.

There were few differences in the selection patterns of respondents from the four broad parts of Europe, other than the increase caused by self-selection and small effects due to geographical proximity (for example, 8% of southern Europeans selected North Africa, in comparison with 3% of northern Europeans). However, one particular result to note is the high score (18%) for Central and South America by respondents in southern Europe (in Spain it was even 33%). Geographical connectivity requirements, although focused within Europe, are fairly widespread and global.

9. *In this paragraph, the percentages reflect the number of times a region has been prioritised as a percentage of the total number of respondents to the survey (4,392). In the next paragraph, the percentages reflect the number of times a region has been prioritised by respondents from a certain region/country as a percentage of the total number of respondents from that region/country. By contrast, the calculations leading to Figure 5.11 exclude the respondents who have not replied to this particular question, and hence result in higher percentages.*

As GÉANT2 provides well-appreciated high-speed connectivity between countries in most of Europe today, it can be expected that an increase in international collaboration as predicted by respondents will increase the technical requirements for better global connectivity.

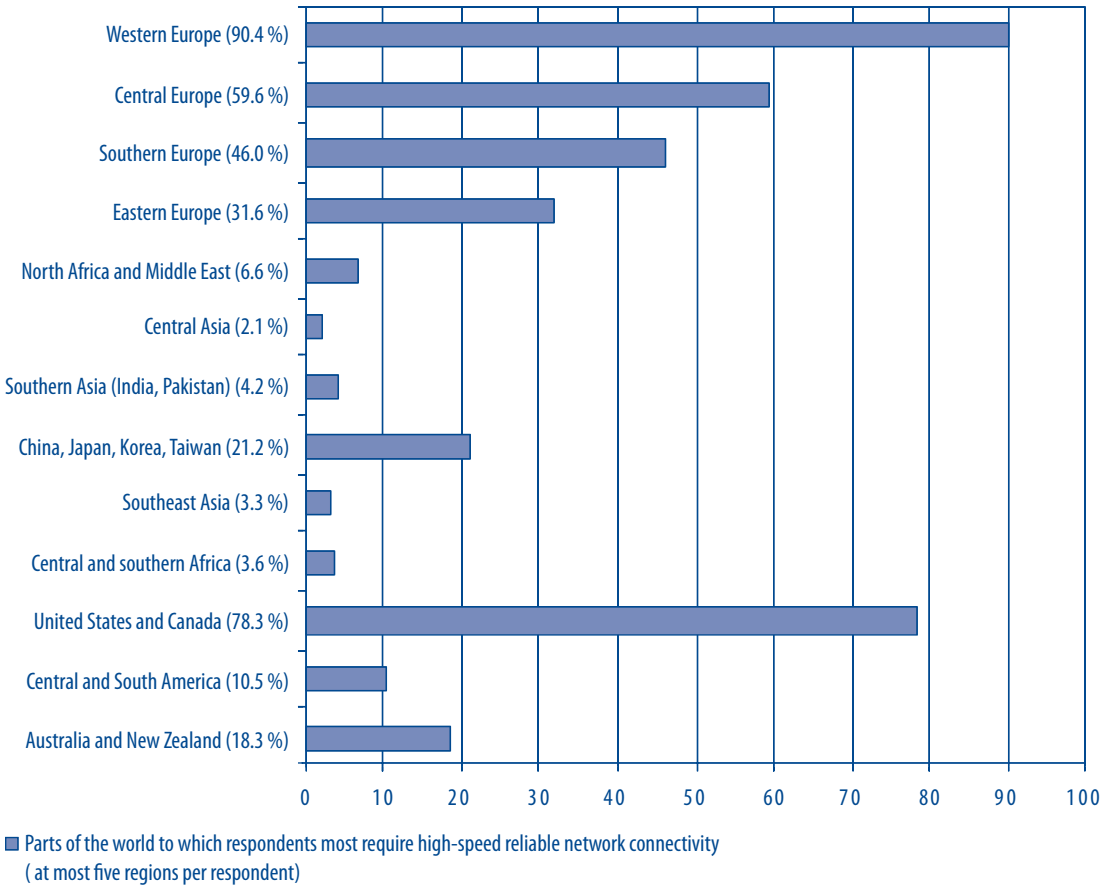

Figure 5.11: Priorities for high-speed reliable network connectivity

6. A set of new ideas

The survey in stage 1 asked participants: *"Ignoring whether it would be technically and financially feasible or not, what would you like to do using data networks for your research or teaching five years from now?"* The most frequently found motifs behind the answers are listed below:

- increase spatial data infrastructures in terms of services;
- share research results more easily;
- exploit further the facilities offered by IT software platforms and design support tools;
- explore and implement novel and more efficient remote-teaching methods;
- exchange data and results interactively with different colleagues;
- have an identical, integrated working environment, at work, at home or travelling;
- run simulations in virtual biological networks;
- run tele-experiments;
- set up sensors in the field that can be monitored continuously from the office;
- simulations and post-processing at distributed sites;
- connect measurement/monitoring equipment in a Grid environment;
- submit and run jobs on the first available supercomputer, independently of its location.

Respondents were also asked how network-related services and tools could be improved. Specific examples are presented below, followed by a table summarising the various inputs from researchers.

Improvement of access to digital libraries

The large majority of interviewees reported that access to digital libraries was very important or essential to their work. Respondents highlighted that digital libraries allow them to keep up to date in a field and access new materials in a quick and easy way from almost anywhere. Digital libraries were also felt to be particularly useful for bibliographic work and proposal writing. They mean that large numbers of journals do not have to be kept in paper form. One respondent pointed out that access to pre-published material speeded up the rate of exchange.

Respondents were also asked in what ways digital libraries or access to them could be improved. Three common areas for improvement were mentioned, namely:

- improvements to search functions;
- an increased number of journals/books available, with better identification;
- greater accessibility to different digital libraries, possibly through greater integration/unification of those currently available.

Other comments referred to improving abstracts, increasing the availability of non-English language work and including data sources.

Improvements of e-learning tools

Some current e-learning users made suggestions how e-learning tools or services could be improved. These included providing training (for both students and research staff) to make the most of available tools and services, making tools simpler, more flexible and more adaptable, and consulting end-users on tool development.

Potential key measures to improve services are listed in Table 6.1.

Keywords	Key messages / measures
Speed	*"Improving computer speed and software"* *"The increase in transfer speed and capacity"* *"Speeds of data transmission"* *"1 Gb/s to the desktop is a must; in our institution 100 Mb/s is still a standard"*
Bandwidth	*"Bandwidth for better data access"* *"Guaranteed bandwidth allocation on demand"*
User-friendliness	*"Easier, user-friendly interface and infrastructure'* *"Improvements in the interface so that the average user can use them without special training"*
Security/confidentiality	*"Security and privacy of the elemental nodes and a guarantee of own priority when logged in without delay in the computer response"*
Accessibility	*"More access to services; they are restricted to few universities and centres"* *"Accessibility for new European countries"*
Software	*"A standardised software and interaction protocol, which allows individual computers to be easily activated for Grid computing, and provides access to network services"* *"Availability of commercial software packages"*
Education/training	*"There has to be increased publicity and training about the potential benefits of network services for individual researchers"* *"User support and training"* *"e-Learning"*
Middleware	*"The network is not the limiting factor for services in Europe; the problem is in middleware and hardware solutions that make some resources unreachable; when this is solved, we will be able to use benefits of more powerful networks"*
Reliability	*"Reliability of computing elements"* *"Reliability of services"*
Cost reduction	*"Decrease the cost of software suitable for parallel and Grid computing"*
Connectivity	*"Better network connections (mainly within institutions)"* *"Connections between the different scientific nodes and countries"*
Standards/compatibility	*"Adoption of standards that allow portability of pipelines between universities"* *"Standardisation between all resources"* *"Compatibility between platform binaries and file formats"*
Infrastructures	*"Research infrastructures"* *"Technical infrastructure"*
Storage	*"Larger storage capacities"*
Management of jobs / parallel processing	*"The main aspect to be developed is computational science so that, knowing the network topology, statistical availability of computers etc., the existing software can run efficiently large-scale parallel programs"* *"It would be important to be able to access parallel computers with a very good interconnectivity and run massively parallel calculations; this does not mean that all nodes should be efficiently interconnected with all others but simply that parallel machines (or clusters of machines) should belong to Grids and be easily addressed and used through them"*
Information on use and existence of Grids	*"We use too much time learning the new technologies"* *"More information on resources in general"*

Table 6.1: Key measures to improve services

These comments basically point at incremental improvements to the existing Internet and Grids. The results suggest that, by far, networking improvements (accessibility etc.) are considered less important than technical developments (speed, bandwidth, user friendliness etc.). In summary, researchers identify a need for more support, for better sustainability of the infrastructures and staff, as well as for a higher degree of virtualisation and correlation of the various tools, services and infrastructures.

7. Summary of the survey results

7.1 Use of network services and tools

The present study provides evidence of the increasing importance that the development of research and education networking and services has had in recent years for the work of researchers in Europe:

- Use of network-related tools and services has become increasingly common among the overwhelming majority of European scientists in the last five years. Still, considerable growth in awareness of these tools and use is anticipated over the next decade.
- Most commonly and frequently used tools are email, distribution lists, wireless access and transfer of large files.
- Most commonly and frequently used services are access to digital libraries and remote databases.
- However, there still appears to be a widespread lack of (detailed) knowledge of many of the main network-related tools and services among 'light users'. Future growth may be dependent on better dissemination of technical information regarding available resources.

The survey respondents indicated that scientists spend an average of 15 hours each week interacting with other researchers and academic teachers via a range of different media. The majority of this time is dedicated to face-to-face meetings and email interaction. However, use of other media, such as videoconferencing, is still increasing and already more frequent in certain fields. Results also showed that a large proportion of time is spent actively using data networks for research or teaching, with a majority of researchers spending over an hour each day on such activities.

Among researchers, three categories of users are identified, which can be linked to the majority of users in a science field:

- light network users: environmental, mathematical and social sciences;
- moderate network users: humanities, life and medical sciences;
- heavy network users: physics and related sciences, materials science and mechanical engineering, IT and computer science, chemistry and chemical engineering.

Lack of knowledge and awareness of National Research and Education Networks and of GÉANT is widespread among researchers. Overall, only 5% of all respondents agreed that the network at their workplace was connected to the pan-European network. However, this can also be seen as an indication of how smoothly and transparently the NRENs and GEANT2 provide services: typically, awareness of the technology and related services rises when the latter fail.

Developments in network-related services over the last five years are seen to have had a (very) positive effect on a number of aspects of research and teaching. In particular, for more than 60% of respondents, access to publications and other information needed for their research has increased very considerably over the last decade. A large number of examples and explanations

were provided as to the positive benefits that have been experienced as a result of network developments, while few drawbacks were identified.

A very large number of respondents use research and education networks mostly for simple applications such as Web browsing and email. A smaller number of end-users engage applications that require streaming media or Virtual Private Networks. Their bandwidth requirements exceed ADSL and extend up to Gigabit Ethernet. Finally, there is a third category of researchers who use special scientific applications such as Grid computing and virtual presence. They need network capacities of one or more Gigabits per second.

Researchers expressed the view that network providers should increase the flow of information - including road maps of future service developments - to their end-user communities. Likewise, network providers should make more educational material available. They should take account of the growth in user expectations in the form of more complex services. They should also plan for good broadband remote access capabilities for researchers at work, at home or away.

7.2 Current and future requirements of researchers and academic teachers with respect to data networks and associated services, applications and IT facilities

In the next 5-10 years, considerable changes are anticipated in the way that researchers and academics work. These changes are expected to have implications for the development of networking and related services. Most respondents expect international collaboration and participation in large-scale collaborative projects to increase substantially in the coming decade.

Comments on how people envision their future use of data networks suggest that there is a widespread desire to increase network-related tools and services for research and teaching activities. Overall, respondents are satisfied with the network infrastructure at their workplace. However, nearly half of the respondents desire more adequate training in network use to improve the quality of their research and teaching. Researchers in environmental sciences and life sciences expressed a dramatic lack of training in network use. Researchers in IT and computer science expressed great dissatisfaction regarding privacy and, especially, security issues. In general, the use of computing Grids, Virtual Organisations and, in particular, lightpaths is hampered by a widespread lack of information and knowledge of what they are. Computing Grids are used by only 6% of respondents for their teaching and research activities, and only an additional 12.6% of respondents expect to use Grids in five years' time. Grids are least known and used by medical-science researchers, social scientists and researchers in the humanities.

It appears that improvements needed to provide better network services are not so much networking improvements but technical improvements: higher-speed guaranteed and extended bandwidth, and easier, user-friendlier interfaces and infrastructure. Over 60% of the respondents do not use nor expect to use large computing facilities and large storage facilities within the next five years. The majority is unaware of the size of these large facilities. In consequence, the facilities appear to be adequate to users' needs today. Nevertheless, a majority of respondents does indeed expect large computing facilities as well as large storage facilities to be inadequate for their needs in 5-10 years' time.

7.3 Conclusion

An important part of the present study was to investigate the future networking requirements of members of the European research community. There is substantial evidence that the network is becoming an essential element in the scientific landscape in all areas of research. There is a distinct high level of satisfaction as regards the services provided today. The study shows that e-Infrastructure is generally accepted as a major facilitator for research and teaching.

The expectations of network users are evolving beyond the provision of pure bandwidth towards the supply of more complex services. There are now concerns about the lack of user knowledge of existing services, tools and software.

There is a general desire among end-users for research and education network organisations to give more attention to end-to-end aspects of communication, including issues related to the quality of service.

General expectations relate to incremental improvements of current technologies and trends. This can be taken as an indicator that networking and Grid technologies have passed through the phase of expansive technology innovation and have now entered a phase of strong technology implementation, in which services are improved and put on a wider application basis.

Another trend is a growing demand for network facilities to support scientific collaboration. Networking at a global level is seen as vital for researchers to make the right strategic decisions and to develop new research fields.

8. Comparison with the SERENATE study

The present study of researchers' requirements is part of the EARNEST foresight study, which can be seen as the successor of the fruitful study carried out in the SERENATE project in the period from May 2002 until December 2003. One of the SERENATE reports was dedicated to the future networking needs of members of the European research community over the next five years or so. Its conclusions were derived primarily by analysing the views of active researchers from a large range of subject disciplines and geographical locations.

Those views were obtained by a questionnaire and by discussions at two workshops. The questionnaire was posted on the Web, targeting individuals who were likely to be using research and education networks. There were almost 500 replies from a wide range of disciplines and sub-disciplines, and with a good geographical distribution over the whole of Europe, like in the present study. The results of that SERENATE report have been kept in mind when preparing the present report in order to track changes or to monitor the evolutions expected at the time of the SERENATE survey. All those points have been integrated in the previously presented results and analysis.

The responses to the SERENATE questionnaire and the experiences of those at the workshops showed that there had been great progress during the years preceding the SERENATE study, so that researchers had a reasonable environment of research and education networking in many parts of Europe. We find similar results in our study, as follows:

- In both studies there was clear evidence of growing network requirements from all areas of research.
- At the time of SERENATE, there were already concerns about security and privacy in the research and education area.
- In the SERENATE study there was already a demand for researchers to be able to access networks from remote locations and for NRENs to increase the flow of information, including making more educational material available.
- NRENs were also requested by SERENATE to take account of the growth in user expectations in the form of more complex services.
- In agreement with the expectations expressed in the SERENATE report about the extension of research networks to education and other user communities, there is now a greater use of network services such as digital libraries and databases.
- There is also a remarkable interest in Grid and high-performance computing as well as in network-related services and tools.
- Nevertheless, it appears that, contrary to the SERENATE expectations, Grid computing with all its related resources remains a service that is requested only by a minority of European researchers.
- According to the SERENATE study, a major source of limited network performance was at the campus level. This does not seem to be the case anymore.
- Even though wireless access does not necessarily drastically change researchers' behaviour in their scientific activities, it is certainly a change that has come and that has become common sooner than expected in the SERENATE survey.

- One conclusion of the previous study was that mobile access to the network was needed. That is even more the case nowadays, due to the heavy use of mobile phones, cameras and large data files produced outside laboratories or the regular place of work.
- The requirement for authentication, authorisation and accounting remains a key operational challenge.

Hence at the level of general conclusions and results, the present survey is a logical extension of the SERENATE report on researchers' requirements, regardless of the difference in sizes and methodologies between the two studies.

9. Recommendations

The research and education networks in Europe are delivering an excellent service, which must be enhanced further. There are several issues of concern, which relate to sustainability, awareness, user support and training. Indeed, there has been an increase in the quality of network services and (data) volume in the five years since the SERENATE survey, but there is still no structural solution in place to make research and teaching more effective.

Below is a list of recommendations regarding services, co-operation and capacities, based on the comments from respondents to the survey. These recommendations were initially suggested by the EARNEST Panel. They were submitted to the eighty stakeholders who participated in the final EARNEST workshop, which was held in La Hulpe near Brussels on 25-26 September 2007. The present list has been amended accordingly and reflects the various comments and discussions during that event.

9.1 Services

Quality services and security

Research networks are technology enablers and catalysts for the proliferation of information and communication technologies in Europe. Quality of services and security issues must be considered. There is a need to update and improve usage policies, security and quality control of data as well as knowledge and information management.

Awareness

More public awareness of network technology and services must be created. Researchers are asking for better training and higher levels of support for many of the network tools and services currently available. Most potential users are not aware of the possibilities and benefits of such services. Training sessions can be part of user meetings and other public events. Training courses aimed at end-users need to be organised frequently, and documentation on the use of services should be made readily available to everyone, for example, in the form of webpages. Hence, wider and better awareness of network technology and services must be reinforced nationally and at a European level, e.g., through Service Knowledge Centres.

User friendly services

Services and support should also be directed towards 'light' or infrequent users. This would increase the access and use of network-related tools and services. Facilitating the tools and services will make it easier for newcomers and 'light users' to work with network services and will create a larger user base, which in turn will give rise to new ideas and tools at a faster rate.

9.2 Co-operation

Simplification and adaptation

New standards, protocols and interfaces need to be defined and developed for better communication between researchers and for new tools, including data repositories and databases. New developments must enhance data security as well.

Interdisciplinary approach

There is a need to build and extend interdisciplinary federation-based, decentralised (or even virtual) infrastructures to support an expanding and diverse community of researchers. It will take years, possibly decades, before the user communities are broad and mature enough to be self-supporting and can easily communicate across disciplines. Targeted trans-disciplinary exchange of experience between communities and, in particular, from more mature communities to new and 'light user' communities, needs to be fostered.

Training

Researchers and all the other users need continuous training in the use of existing and upcoming tools. A relatively modest investment in promotional videos, online training material and brief explanatory documents would yield enormous benefits throughout the European higher-education sector. Transfer of knowledge and tools for e-teaching are particular topics to address.

9.3 Capacities

Sustainability and interdependency

It is important to enhance the interoperability of facilities and services with network control and management and to develop common operational models to accommodate new and safe services. High-quality security standards for data and users are a precondition for high-quality interoperability. There are significant opportunities for mobile networking that need to be embedded in existing structures. European organisations could investigate and assess these opportunities. If necessary, a pan-European mobile networking environment for researchers, including access to storage, computing and data facilities, should be created. Many institutions or network-related facilities do not have enough human resources to exploit fully the benefits of their level of investment in the technology. Moreover, career development for researchers in this field has so far been neglected and needs fresh consideration. Therefore, not only is it necessary to sustain investment in the infrastructure, but it is also crucial to invest in the most competent experts with long-term career plans.

Virtualisation

Users want to have services delivered and do not really want to bother with the exact location or technology of connectivity of the network service. The situation resembles very much the electricity grid: users do not really want to know where the electricity is produced or via which pathways is it delivered. As a consequence, Europe should promote the virtual provision of services, including computing resources, storage services, data-repository services, collaborative tools and

communication services in the most convenient way for researchers. Simultaneously, issues of safety standards and data security are of high importance as a protection against misuse of virtual services. It is necessary to design a robust distribution of facilities across Europe that can interoperate and bridge the gap of the digital divide. This would create a rich ecology of dedicated facilities for European researchers. Europe could then become a hub for virtual communities.

Support

Several services and network tools should be promoted and supported more actively, such as videoconferencing facilities. Institutions must be able to provide complete technical support to end-users, especially to inexperienced or occasional users, as a way of promoting the network service. This should include not only the network-related aspects of the service but also the provision of modern equipment and auxiliaries and guarantee high security and data standards. Modular and decentralised development of tools and services should be implemented via dedicated European virtual organisations and communities. Existing and emerging services, tools and software require structured financial support for development, maintenance and use at both national and European levels.

9.4 Summary

Key results and recommendations in the three main areas of the present study on researchers' requirements can be summarised as follows.

Area	Recommendations
Services	Quality services and security: there is a need to upgrade and improve usage policies, security, and quality control of data and information management.
	Awareness: wider and better awareness of network technology and services must be reinforced nationally and at a European level, e.g., through Service Knowledge Centres.
	User-friendly services: services, access and support should also be directed towards 'light' or infrequent users.
Co-operation	Simplification and adaptation: new standards, protocols and interfaces need to be developed for new and existing technologies, including data facilities.
	Interdisciplinary approach: there is a need to build and extend interdisciplinary federation-based, decentralised (or even virtual) infrastructures to support an expanding and diverse community of researchers.
	Training: there is a need for continuous training in the use of existing and upcoming tools through new media such as videos and online training material.
Capacities	Interdependency: it is important to enhance the interoperability of facilities and services.
	Sustainability (I): European researchers and institutions should investigate and assess interoperability, training and standardisation.
	Sustainability (II): career development for researchers in this field is necessary; therefore, it is crucial to invest in the most competent experts with long-term career plans.
	Virtualisation: European institutions should promote the provision of virtual services, including computing resources, storage services, data-repository services, collaborative tools and communication services; Europe could then become a hub for virtual communities.
	Support (I): modular and decentralised development of tools and services should be implemented via dedicated European virtual organisations and communities
	Support (II): existing and emerging services, tools and software require structured financial support for development, maintenance and use at both national and European levels.

Table 9.1: Summary of key results and recommendations

10. References

EARNEST	http://www.terena.org/activities/earnest/
GN2	http://www.geant2.net/server/show/nav.749
SERENATE	http://www.serenate.org/

11. Acronyms

ADSL	Asymmetric Digital Subscriber Line
CPU	Central Processing Unit
EARNEST	Education And Research Networking Evolution Study
ERA	European Research Area
ESF	European Science Foundation
FLOPS	Floating Point Operations Per Second
Gb/s	Gigabits per second
GÉANT	Gigabit European Academic Network Technology
GN2	Multi-Gigabit European Academic Network
GNU	GNU's Not Unix
IT	Information Technology
Mb/s	Megabits per second
N/A	Not Applicable
NREN	National Research and Education Network
NREN	National Research and Education Networking organisation
PESC	Physical and Engineering Sciences
SERENATE	Study into European Research and Education Networking As Targeted by *e*Europe
TB	Tera Byte
TEN-155	Trans-European Network Interconnect at 155 Mb/s
TEN-34	Trans-European Network Interconnect at 34 Mb/s
TFlops	Tera FLOPS
VPN	Virtual Private Network

Appendix 1

Survey Questionnaire

Respondent Identification

A. Please provide the following information about yourself and your work
First name, Family name, Email address

B. Affiliation (please tick one)
- University, institute for higher education
- Research institute - wholly publicly funded
- Research institute - funded from a mix of public and private sources
- Private Company, laboratory or institute
- Other (please specify)

C. In which country is your regular place of work?
- AFGHANISTAN
- ……
- ZIMBABWE

D. Which of the following best describes your research?
- Mathematical sciences
- Physics and related sciences
- Chemistry and chemical engineering
- Materials science and mechanical engineering
- IT and computer science
- Environmental sciences (incl. earth sciences, marine sciences…)
- Life sciences (incl. biology, biotechnology…)
- Medical sciences
- Social sciences
- Humanities

E. Within this area, what is your specific research field (e.g. particle physics, industrial sociology…)?

Usage

1/16. How often do you use the following TOOLS for your research or teaching activities?
(Daily; Weekly; Less often; Not yet, but expect to within 2-3 years; Never; Don't know)
- Person-to-person e-mail
- Email discussion/distribution lists
- Instant messaging
- Wiki
- Video-conferencing
- IP telephony
- IPv6
- VPNs (Virtual Private Networks)
- Bandwidth reservation
- Wireless access at work

- Wireless access at other institutions
- Encryption of data
- Transfer of large files

2/16. How often do you use the following SERVICES for your research or teaching activities?
(Daily; Weekly; Less often; Not yet, but expect to within 2-3 years; Never; Don't know)

- Access to digital libraries
- Access to remote databases
- Remote control of scientific instruments
- High-resolution visualisation of data
- Large computing facilities
- Computing Grids
- e-learning services for teaching activities

Usage (2)

3/16. How much of your time each day do you spend actively using data networks for research or teaching?

- Less than 1 hour
- Between 1 and 2 hours
- Between 2 and 4 hours
- Between 4 and 8 hours
- More than 8 hours

4/16. Approximately how many hours do you spend each week interacting with other researchers via the following media?

- Face-to-face meetings
- Phone
- Email
- Videoconferencing
- Fax
- Postal letters

Usage (3)

5/16. How have the following been affected by developments in network-related services over the last 5-10 years?
(Negatively; Not at all; Positively (e.g. factor 2); Very positively (e.g. factor 10); Don't know)

- The rate at which you publish
- Access to others' publications
- Access to other information needed for your research
- Access to new fields of research
- Funding opportunities
- Your ability to obtain information on meetings and conferences
- The ability to take consensus-built decisions
- The ability to recruit good people, e.g. through electronic job ads
- The availability of educational material
- Your own career development, through monitoring the job market electronically

5a/16. If you answered that developments have had a 'negative' or 'very positive' effect in any of these areas: Could you provide an example of a service where this has been the case? How has it changed your work?

Satisfaction

6/16. Here are a number of statements describing how you assess the network infrastructure you use from your usual workplace. Please indicate to what extent they apply.
(Strongly disagree; Disagree; Agree; Strongly agree; Don't know / No opinion)

- The network infrastructure offers a continuous and reliable service
- The network infrastructure allows me to use all the applications I need
- The network infrastructure has enough speed / capacity
- The network infrastructure preserves privacy and confidentiality of data or communications
- The network infrastructure enables authentication of data or communications
- The network infrastructure guarantees security, protection of data or resources against accident or attack
- Your IT support is rapid and effective
- You receive adequate training in network use to improve the quality of your research or teaching

6a/16. Where you have 'strongly disagreed' with a statement, could you please give details?

User Needs

7/16. How do you expect the following areas to develop over the next 5-10 years?
(Decrease significantly; Decrease slightly; Stay approximately the same; Increase slightly; Increase significantly; Don't know; N/A)

- The extent to which you collaborate with other researchers in your country
- The extent to which you collaborate with other researchers abroad
- The extent to which you teach at a distance
- The extent to which you work in large collaborative projects
- The extent to which digital communications replace travel
- The extent to which you will telework

8/16. Ignoring whether it would be technically and financially feasible or not, what would you like to do 5 years from now using data networks for your research or teaching that you are not doing at present?

User Needs (2)

9/16. To which parts of the world do you most require high-speed reliable network connectivity for your work? (mark at most five)

- Western Europe
- Central Europe
- Southern Europe
- Eastern Europe
- North Africa and the Middle East
- Central Asia
- Southern Asia (India, Pakistan)
- China, Japan, Korea, Taiwan
- Southeast Asia
- Central and southern Africa
- United States and Canada
- Central and South America
- Australia and New Zealand

10/16. Please select the statement below that best describes your knowledge and use of Grid computing.

- I am using Grids for my research or teaching
- Grids are being used in my area of research and teaching, but I am not involved myself
- I expect that in 5 years' time I will be using Grids for my research or teaching
- I have heard of Grids but I don't know about the use of Grids in my area of research or teaching
- I do not know what Grids are

User Needs (3)

10a/16. Could you provide an example of the main areas of application and benefit of Grids?

10b/16. Which aspects of networking should be improved to achieve better Grid services?

Virtual Organisations

A Virtual Organisation is a set of individuals or organisations that collaborate via data networks. They share a subset of their resources via those networks at their discretion and each under their own conditions.

11/16. Please select the statement below that best describes your knowledge and involvement in Virtual Organisations

- I belong to a Virtual Organisation in my area of research or teaching
- Virtual Organisations exist in my area of research or teaching, but I am not involved myself
- I expect that in 5 years' time I will be involved in a Virtual Organisation in my area of research or teaching
- I have heard of Virtual Organisations but I do not know about their existence in my area of research or teaching
- I have not heard about Virtual Organisations

Virtual Organisations (2)

11a/16. In your experience, what are the benefits to researchers and academic teachers of Virtual Organisations? Please could you list some?

Infrastructure

12/16. Is the local network at your institution connected to a national research and education network?
(Yes / No / Don't know)

Infrastructure (2)

12a/16. What is the name of that national research and education network?

- ACOnet
- AMRES
- …….
- Wissenschaftsnetz
- X-WiN
- Other, please specify

12b/16 Who funds that national research and education network?

- It is entirely funded by the national government or government agencies

- It is entirely funded by other sources
- It is partly funded by government (agencies) and partly by other sources
- Don't know
- Other (please specify)

Infrastructure (3)

12c/16. Is the local network at your institution (via another network) connected to GEANT, the pan-European Gigabit research network?
(Yes / No / Don't Know)

Computing Facilities

13/16. Do you use large scientific computing facilities, or expect to do so within the next 5-10 years?
(Yes / No/ Don't know)

Computing Facilities (2)

13a/16. How large is the largest computing facility that you have access to?

- Less than 1 TFlops
- Between 1 and 3 TFlops
- Between 3 and 5 TFlops
- Between 5 and 10 TFlops
- Between 10 and 50 TFlops
- More than 50 TFlops
- Don't know

13b/16. How adequate is this computing facility to your needs today / in 5-10 years time?
(Much more than I need; More than I need; Satisfactory; Inadequate; Very Inadequate; Don't know; N/A)

- Adequacy today
- Adequacy in 5-10 years

13c/16. Is this computing facility…

- An institutional infrastructure ?
- A regional infrastructure ?
- A national infrastructure ?
- A private infrastructure ?
- Don't know

Storage Facilities

14/16. Do you use large data storage facilities, or expect to do so within the next 5-10 years?
(Yes / No / Don't know)

Storage Facilities (2)

14a/16. How large is the largest storage facility you have access to?

- Less than 1 TB
- Between 1 and 5 TB
- Between 5 and 10 TB
- Between 10 and 50 TB
- Between 50 and 100 TB

- More than 100 TB
- Don't know

14b/16. How adequate is this storage facility to your needs today / in 5 - 10 years time?
(Much more than I need; More than I need; Satisfactory; Inadequate; Very inadequate; Don't know, N/A)

- Adequacy today
- Adequacy in 5-10 years

Lightpaths

Lightpaths are separate, dedicated, guaranteed and reliable optical connections over the network infrastructure interconnecting a limited number of locations at very high speeds (Gigabits per second).

15/16. Have you heard about 'Lightpaths'?
(Yes / No)

Lightpaths (2)

15a/16. Please select the statement below that best describes your expectations about the use of Lightpaths in your research area:

- Lightpaths are already being used in my research area
- I expect that Lightpaths will be used in my research area within the next 5 years
- I don't expect that Lightpaths will be used in my research area within the next 5 years
- I don't know

Conclusions

16/16. Do you have any further comments that you would like to make?
When the survey has been analysed, would you like us to send you a link to the results?
(Yes / No)