Some Illusions and Conclusions
I know of physicists who think that with the end of big programmes they will get more money. I repeat that "les vases ne communiquent plus". There are special decisions for large facilities so they stand alone. Meanwhile, the golden years of megascience have ended as there is no longer the concern of the general public, and hence of government. Many people feel that science cannot directly solve the unemployment problem. So while it is still evident to some that science is necessary, we cannot expect that its share of resources will increase faster than the average rate of growth of a country's wealth.

In expecting not to be appreciated as much as in the past, we have to demonstrate the usefulness of claims. Moreover, when arguing the case for facilities we must not forget that their running costs are important. The significance of this remark is easily appreciated by noting that CERN's annual operating budget of 900 M NSF is not very much smaller than the construction cost of LHC (about 2300 M NSF). With new investments, we have to be sure that the annual running costs are covered without jeopardising physics as a whole.

We must also remember that facilities are becoming more international. One has to start discussions on a new facility with all colleagues before promoting it. This was not exactly the rule in the past. Recognizing such issues is becoming vital to us all because it is becoming increasingly common for the average physicist to work at or in close contact with a facility.

Hubert Curien, the President of the CERN Council, was the President of Académie Européenne in 1988-89 and served as France's Minister of Science in 1984-86.

PLenary talks

Key Issues Demonstrated

The technical presentations at the 1994 EPS Large Facilities in Physics Conference illustrated — often in a dramatic way — the trend towards facilities that tackle world-class research goals, extend into a broad range of fields, exploit technology at its limits and even beyond to provide major increases in capabilities, and are increasingly based on multidisciplinarity and international cooperation from the start.

HIGH ENERGY PHYSICS

Frontiers Call for Commitments
C. Llewellyn Smith, CERN's Director-General, set the pattern in explaining why the standard model of particle physics is too "baroque" and logically incomplete despite its great success. CERN's LHC machine aims to address many of the open questions so it is undoubtedly the right machine at the right time, for new physics must emerge to recover from the closure of the SSC.

Françoise Pradere (on the left), Coordinator of the OECD Megascience Unit, with Günter Flügge, Chairman of the European Committee for Future Accelerators.

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NUCLEAR AND ATOMIC PHYSICS

Spreading through Large and Small

The energy available for heavy-ion physics continues to increase by an order of magnitude with each new generation of machine, the most modern of which (e.g., GSI Darmstadt's ESR/SIS complex) can be filled to physics limits at low atomic numbers. H.J. Specht, the GSI Director, gave a very thorough review of heavy-ion physics where significant progress has recently been made using heavy-ion collisions to tackle one of the principle goals, namely, critical behaviour in finite systems. The dream of physics in ion-storage cooler rings is the study of single atoms. Some impressive X-ray spectroscopy results have been reported this year for 

Emerging in New Areas

The diffusion of facilities into traditional small science, is perhaps epitomized by centres offering access to unique collections of lasers or to a single large machine, that need not be very large if the technology is changing very quickly. The last is the case for the 2 MSUS "big table-top" Ti:sapphire lasers now being set up in at least four European laboratories. Owing to their flexibility and scalability, high-power, short-pulse lasers will become the workhorse of short pulse/high peak power work. P. Lambropoulos from the Max-Planck Institute for Quantum Optics in Garching pointed out that focussed peak powers of 10^{10}-10^{11} W/cm^2 are available, approaching the power (10^{20} W/cm^2) for intense free-electron lasers. Another important new direction is the generation of X-rays using multiphoton processes to replace to some extent synchrotron sources. In general, one should distinguish high-power laser facilities (6 in Europe), offering high-brilliance sources of cold-ion beams and the storage of exotic atoms, that these facilities are providing new experimental possibilities in microscopic spectroscopy and reactions, as well as data of extreme importance for astrophysics and plasma physics.

CONDESED MATTER

Breakthrough Increase in Capabilities

The recent and very successful commissioning of the European Synchrotron Radiation Facility (ESRF) and its above-design performance are naturally drawing attention to other, complementary facilities in the field of ion-storage cooler rings. R. Schuch from Stockholm illustrated this trend by describing studies of the various types of recombination that are being carried out using electron-ion interaction in rings. By

Handing Complementarity

Several facilities-based techniques demonstrate a high degree of complementarity. This is especially so for synchrotron radiation and neutron sources that are used extensively for statistical studies in condensed matter as each offers unique features. Establishing appropriate balances, and maybe organizational structures, then become important. Synchrotron sources in Europe now serve 6000 users, and the number will double by the year 2000. V.L. Aksenov (JINR, Dubna) reported that neutron sources currently have some 4500 users in the OECD countries, with an estimated 7000 by the year 2020. Reactor sources satisfy most of the neutron needs, and world-wide there are about 50 steady-state sources available for research. However, most are approaching the end of their service lives and only 10 have been upgraded to modern standards. Moreover, only 6 of today's high-flux reactors (HFRs) are high peak power/ultrashort pulse table-top systems (currently 3 in Europe) and industrially orientated laser facilities.

The increase in the brilliance of X-rays plotted on a logarithmic scale. The insertion devices at the ESRF offer high-energy X-ray beams which are so bright that they visibly ionize the air.
that four pulsed neutron spallation sour-
tive when it comes to cost and perceived
vanced Neutron Source project in the US Is
A major reactor project (PIK, St. Petersburg)
today's leading spallation source (ISIS in the
The last category includes the regional Aus-
several are being built or are under study.
the removal of burnt residues, steady-state
ments and the empirical scaling laws upon
Large (1 GW) and Is at least 50 years away;
most of Grenoble's upgrading efforts is going into
short pulse (0.1 s), 100 T unit for which
design studies have been carried out with
larger (1 GW) and Is at least 50 years away;
were taken up
The inertial approach to fusion has seen
of ":cost drift". This illustrates the difficulties
in negotiating global projects of a scale that "dictate" an international col-
the removal of burnt residues, steady-state
Keeping Options Open
In Europe, operation of the JET torus, which is too small to induce ignition, with the
commissioned the world's best cloud muon channel offering a very high solid angle.
In Europe, operation of the JET torus, which is too small to induce ignition, with the
The inertial approach to fusion has seen
much less effort than magnetic confinement.
A major reactor project (PIK, St. Petersburg) remains uncertain and the 1500 M$US Ad-
B. Lengeler from CERN explained that four pulsed neutron spallation sour-
cientific and to share expertise — an approach
Coordinating the balance between these various levels and types of fac-
ities will take careful consideration, so it is not surprising that several consultative and
discussion bodies have taken an interest.
ad hoc Arrangements Preferred
The condensed matter community is making increased use of advanced high
magnetic fields offered by a growing num-
ber of centres. But it also tries to maintain a
friendly rivalry between centres as the phy-
sics goals are challenging. P. Wyder, the
Director of the High Magnetic Field Labora-
yory level to minimize unnecessary duplica-
tion and to share expertise — an approach
that stems from the small-science/small
Collections. The 5600 M$US ITER tokamak is
The condensed matter community is making increased use of advanced high
magnetic fields offered by a growing num-
eries at the labora-
tories (PSI, TRIUMF, LAMPF, RAL) since they
are invariably produced at medium-energy hadron accelerators.
The PSI and TRIUMF in Canada domi-
nate with beams in six areas and five beams, respectively, and the PSI recently
EDS: T. Yamazaki
FUSION
Global Projects Are Not Easy
According to C. Maisonneau, the Director of
that muon beams are associated with four large facili-
ties (PSI, TRIUMF, LAMPF, RAL) since they
are invariably produced at medium-energy hadron accelerators.
The PSI and TRIUMF in Canada domi-
nate with beams in six areas and five beams, respectively, and the PSI recently
exploration programme carried out within a
loose framework, R. Bock (GSI Darmstadt) believes that the time has come for a Euro-
pean study of a High Intensity Ignition Facili-
ity representing the logical next step (a ded-
lcated accelerator facility to examine the
remaining key issues and to demonstrate ignition). Roughly 1% of the EC fusion
budget is needed to develop a concept and to come up with a coherent set of param-
ters. The US, meanwhile, plans to upgrade
its large NOVA laser facility and is consi-
dering an ion-beam driven ignition facility based on different type of ignac.
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Balancing New and Established

Turning to ground-based astronomical facilities, T.J.L. Courvoisier from Geneva gave a remarkably concise review of much that has been achieved in increasing parameter space these past decades (see basic domain now extends over 15 decades, detector sensitivity increased by 100-times, spectral resolution increased by 10-times, angular resolution decreased from 1 to $10^{-3}$ arcsec, line resolution decreased from minutes to less than masec of arc). This has naturally led to unexpected observations and an increased intellectual challenge to solve several basic questions. His talk pin-pointed how advances in a field often come by blending radically new techniques with the evolution of older ones. In optical astronomy, using advanced technologies (e.g., adaptive optics) one is now almost at the diffraction limit and telescopes in the 8-10 m class (with a total area of 620 m² compared to 150 m² for the previous generation of 3.5-6 m devices) are starting to come on.

Very large baseline interferometry facilities for radio astronomy. Indicated are the EVN network of European telescopes, the North America-based Very Large Baseline Array (10 x 25 m antennae) and the Asia Pacific Telescope.

PHYSICS

Technology ..... Offers Opportunities

By describing the proposal to the European Space Agency (ESA) for an extremely elegant space-based gravity wave interferometer called LISA in response to a recent call for mission concepts, K. Danzmann from Hannover gave a remarkably professional account of the opportunities offered to fundamental physics by exploiting modern technology. (The ESA Survey Committee has recommended LISA for study at as a possible Cornerstone mission — see page 184.)

Danzmann spoke about gravity wave interferometers. He said that the challenge is to continue to organize efficient international collaboration. New Facilities Generate Technology

Last year's Nobel prize in physics gave solid evidence that gravity waves exist, but they have so far escaped detection. Gravity-wave detectors are heading in the direction of becoming astronomical facilities with the construction of km-sized interferometers (four such installations working in coincidence would permit "true" astronomy). The US is constructing the first of the two LIGO devices (first coincidence runs in late 1995, final commissioning 1998) and has built VIRGO (first tests in 2000). They have similar levels of cost (about 80 MECU per device) and annual funding. G. Fontaine (In2P3/CNRS, Paris) explained that all three are based on a Fabry-Perot system with laser recycling. The technical challenges (which lead to an excellent industrial spin-off) are severe. In the case of VIRGO, the mechanical suspension system is being designed for an attenuation of $10^{10}$ ($10^9$ has been achieved), the required laser stability has been reached at 8 W (the target is 10 W), and mirrors have been ground to give the required 1-ppm losses. The end result will be a device that extends considerably the observable parameter space relative to that for the cryogenic (100 mK) resonating bar detectors which started to enter service last year (3 will be operating by 1995). Meanwhile, a German-UK project to build in Hannover an advanced, medium-sized interferometer based on signal recycling to test future upgrade paths is likely to receive the go-ahead after being recast in a smaller form. It is the 10-12 MDM GEO 600 twin-arm interferometer with 1/5 the length of VIRGO's arms and 3-times less sensitivity.

... But More is Needed to Extend Limits

Handling complex technology in the extremely industrial world of tendered equipment has some drawbacks. However, P.M. Bonnet, Director of ESA's Science Program Committee, remarked, "Without the 2000s MCCU (and increasing) for the US and 168 MCCU (and increasing) for Japan. The trend has been to a massive increase in the size of satellites as more powerful launchers became available. However, the cost of both the large Cornerstone Missions and the Medium-sized Missions have levelled out so there has not been a continuous escalation. More significantly, there has been a constant 5-6 year interval between missions in spite of the considerably increased complexity — something that is important for scientists. Space scientists have tended to "think big" by seeking increased performance, collecting area arms resolution, and have not limited their ambitions. So the statistics (see figures) suggest we may be..."
"hitting limits", both in terms of budgets and launchers. Hence, the time has come to think seriously about more new technology, notably miniaturization (the US Clementine spacecraft is a good example). Meanwhile, one has to be careful that partners are "reliable" when extending international cooperation to generate critical masses.

Structures to Handle Facilities' Growth

During the past decades, physics has been characterized by "dogs that did not bark" (null signals) involving such things as proton decay, magnetic monopoles, neutrinoless decay and dark matter. However, there have been some positive results and L. Maiani, the President of Italy's INFN, in reviewing underground and underwater facilities for astrophysics highlighted work on supernovae and solar neutrinos. He concentrated on the latter to illustrate the growing importance of large facilities such as the Gran Sasso Laboratory for astrophysics. Solar neutrinos from beryllium have been seen and the neutrino spectrum is inconsistent with the standard solar model. Two major new underground neutrino experiments come on-line shortly (Sudbury in 1995; Super Kamio-kande in 1996) and there are good possibilities that Borexino will be approved. The main question now is if third-generation experiments will be needed. There is also continuing progress in the field of underwater (under-ice) neutrino telescopes, and long-baseline experiments will be needed to eventually check neutrino oscillations. With this expansion, there is a need to organize in some way the development of the various facilities. An inter-regional approach, that addresses increasingly finer structures, is one proposal for tackling an issue that will repeatedly challenge physics as it plans the ever more powerful and sophisticated instruments that are essential for future advances.

Luciano Maiani, on the left, spoke about Earth-based facilities for astrophysics.

The evolution of ESA's Space Science Missions.

On the left there has been a massive increase in the payloads as more powerful launchers became available. On the right: the costs (in millions of Accounting Units) of the large CS-Class (Cornerstone) and M-Class (Medium-sized) missions have reached a plateau in spite of increasing complexity.

1994 EPS Large Facilities in Physics Conference

ROUND-TABLE DISCUSSIONS

Science has a place for all styles, whether collective, cooperative or small-group based. Attracting young people into the whole of science, both large- and small-scale, is appropriate and would be most useful. Facilities can help by stressing ways to channel creativity and to transfer technology, and by training engineers. The level of public support for science seems good, but the interest is not translated into more opportunities for young people since the mechanisms to promote science are inadequate.

Facilities, and more recently large cooperative science, is extending into the traditional small-science fields, with traditional large science providing a valid model. Facilities have a special role to play in some countries, where special organizational structures may be appropriate. Specific statistics about funding should help in reducing tension between the different branches of science.

Discussing the correct balance between large and small science was for Hans Chang (Director of the Dutch funding agency FOM) an irrelevant, emotional issue stirred up by governments seeking reductions in difficult economic times. Physics certainly needs to stand united, but this will be difficult when it comes to bread and butter issues, especially since certain fields need a boost to maintain them as interesting to areas outside physics. However, he questioned the wisdom of placing large facilities in a special category to insulate them somewhat because they are showing traditional small-science fields the way forward. The important feature today is that owing to improved communications and to transfer technology, and by training engineers.

Attracting Young People

Aside from asking whether a particular field delivers high-quality results, the real question is whether or not large science attracts young people, for facilities will come to a premature end not from a lack of money, but through a lack of talented young people.

The large collaborations found at some facilities are often seen by those working in small groups elsewhere as being unattractive. Herwig Schopper, the conference chairman, stressed that the small-group culture in fact thrives inside most facilities. The real drawback is that their scientists now often only work on a few experiments in a lifetime, so there is a need to make better use of creativity.

After an animated discussion, speakers agreed that there was a "place for all" — for large collaborations and small university-based groups. Any tension arising from differences in the working styles cannot be too great because people in both environments appreciate each others' efforts, especially in theory where ideas move freely. As Norbert Kroo, EPS President and Director of the Insti-