communicate any longer.

Consider some features of the space station. Its cost was estimated at M$US 33000, and M$US 9000 has already been spent; the US Congress asked for a price cut and the cost is now estimated as M$US 19000. This is not the way to generate confidence in a project. In the case of particle physics, the closure of the Superconducting Super Collider project was a drama for many colleagues in the US: it was clearly a bit too expensive and its estimated price increased too rapidly. I shall not comment on its management, but merely note that Congress would not accept the cost. The price was too high because the project started from scratch. This is an important point as it is necessary to be progressive by making use of existing facilities. By contrast, the price of the LHC is not too high and I am sure that the machine will be achievable.

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 MSFR is not very much smaller than the construction cost of LHC (about 2300 MSFR). 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 Academia Europaea in 1988-93 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 on approaching the 1 TeV bench-mark at the quark-quark level. He summarised the status of the negotiations to fund LHC with the hope that it will be "constructed as a global partnership". After summarising HERA's recent contributions towards unifying the electromagnetic and weak forces, he turned to other activities in high-energy physics (HEP) in Europe to illustrate the overall depth of the programme. This includes new work at CERN's LEAR which announced a week earlier a spectacular (10^4) improvement in the accuracy of the measured mass differences between the proton and the antiproton (to 1 in 10^9).

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

In the US, the Drell report on HEP has recommended a boost in spending as a way to recover from the closure of the SSC project (Congress has now to decide). According to S. Wojcicki from SLAC, some 75-85% of the US's HEP effort is spent at four main centres. It will ensure that the versatile accelerator complexes which have evolved over 25 years will remain at the frontiers for the decade to come. FERMILAB is carrying out a 300 M$US upgrade of its $p\bar{p}$-collider (by autumn 1998) and a new fixed-target facility is planned; Brookhaven is constructing the heavy-ion collider RHIC; SLAC has the go-ahead to build an ambitious B-factory, and Cornell will upgrade its CESR e^+e^- facility in three phases by 1998 to give a monopoly on e^+e^- collisions at the $b\bar{b}$ threshold.

International Cooperation a Major Item

The 14 M$US spent on overseas collaborations these last 10 years by Japan's HEP community demonstrates a strong commitment to international activities. And as H. Sugawara, the Director of Japan's national HEP laboratory (KEK), explained, this is carried out in parallel with a major national HEP programme. Under construction are the new Super Kamiokande detector (first data in late-1996) and a B-factory at KEK (commissioning at the end of 1998), where much effort was required to deal with a hitherto unknown instability arising from the very heavy beam loading. The Japan Linear Collider project (1000 M$US; 3-4 years construction) is still being planned as a national project (11 sites have recently been short-listed) in spite of the extensive international collaboration in the field. It has been decided to join RHIC, a 100 M$US τ-charm factory in China, and LHC's ATLAS experiment. A representative committee has recommended that any SSC engagement be replaced by LHC, but it may be hard to keep the government's high level of interest in LHC if the decision to go ahead is deferred for too long. The US is "psychologically" in the same position: there is momentum to support LHC (senior officials have talked about a 400 M$US contribution) but it will not last for ever.

Advanced Technology Essential

B.H. Wiik, the Director of DESY, Hamburg, discussed in more detail how R&D, largely at a technical level, for a future linear collider is progressing at several laboratories around the world in the framework of a collaboration. Physics machines of this type are now feasible owing to the development of control systems. Axel Daneels, who chairs the EPS Interdivisional Group for control systems, described how critical such systems have become; they are costly, essential for good performance and offer much *via* integration into an overall management system. D.J. Wallace (Loughborough) explained that the rate of technical development is also not easing up in supercomputing, where physics remains a driver owing to its computational needs. But it is the commercial and policy issues that interest him most. Europe is clearly well behind the US when it comes to supercomputing resources. This can be changed if funding agencies take into account the whole life cycle of a facility as witnessed by all participants. Telecommunications are also inadequate, largely owing to arbitrarily high tariffs and weak international initiatives.

NUCLEAR AND ATOMIC PHYSICS

Spreading through Large and Small

The energy available for heavy-ion physics continue to increase by an order of magnitude with each successive 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 U^{92+}, heralding the possibility that the techniques used will achieve the same precision as laser spectroscopy. But developing applications of significance for the general public, such as ion therapy and inertial confinement fusion, must not be ignored.

Atomic and molecular physics, a traditional "small-scale science", is also starting to acquire major user facilities in the form 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 offering high-brilliance sources of cold-ion beams and the storage of exotic atoms, these facilities are providing new experimental access to atomic and molecular spectroscopy and reactions, as well as data of extreme importance for astrophysics and plasma physics.

Emerging in New Areas

The diffusion of facilities into traditional small science is perhaps epitomised 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 M$US "big table-top" Ti-sapphire lasers now being set up in at least four European laboratories. Owing to their flexibility and broad bandwidth, they 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^{16}-10^{18} W/cm^2 are available, approaching the power (10^{20} W/cm^2) for interesting relativistic effects. 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 large high-power laser facilities (6 in Europe), high peak power/ultrashort pulse table-top systems (currently 3 in Europe) and industrially-orientated laser facilities.

Herbert Walther (on the left) with Paul Kienle.

Collaboration Grows in Nuclear Physics

J. Arvieux (CEN/Saclay) reviewed **lepton probes** in nuclear physics, and described the ELFE project for a 15-30 GeV DC (50 μA) accelerator that would address physics at the threshold between confinement and hadronization in nuclei. NuPECC's final recommendations are due this month and the plan is to set up a European collaboration in early-1995. P. Twin (Liverpool) then reviewed the increasing level of European activity that is focussed around the EUROBALL Collaboration's plans in **γ-ray spectroscopy** based on a first-phase 4π-array in Legnaro with the simultaneous development of advanced detectors.

CONDENSED MATTER

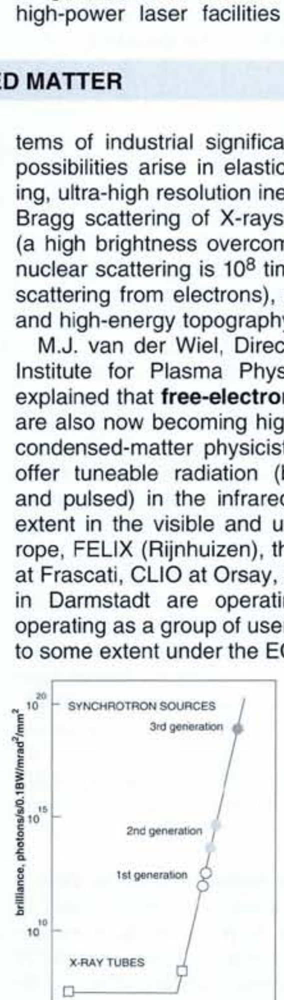
Breakthrough Increase in Capabilities

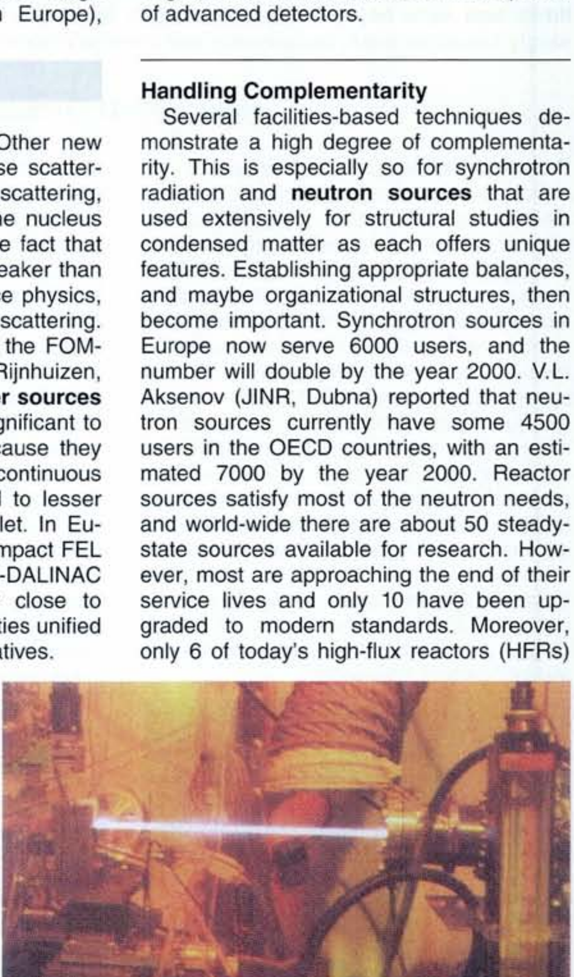
The recent and very successful commissioning of the European Synchrotron Radiation Facility (ESRF) and its above-design performance are naturally drawing attention to the possibilities being opened up by the new, third-generation **synchrotron light sources**, and their impact on the condensed-matter community. The ESRF literally blazes the trail as similar machines are still under construction (APS in the USA and Spring-B in Japan for hard X-rays). In the UV and soft X-ray range, ELETTRA (Trieste) and the SRRC in Taiwan are now operating, and three other machines are being built (ALS, BESSY II and MAX II). Y. Petroff, the ESRF Director-General, highlighted the dramatic improvements in source brightness (see figure) and beam optics. Thus, in the X-ray range, the ESRF has already achieved a beam divergence at 10 keV similar to that for an ideal coherent source, namely a laser beam. Special zone plates have been developed for manipulating and focussing beams, the breakthrough coming with systems giving 10^9 photons/s at a beam current of 100 mÅ in an energy bandwidth $\Delta E/E$ of 10^{-5} focussed over an area of 1 μm^2. Life sciences will benefit most from the new capabilities as one can determine the structures of proteins and viruses using small (10-20 μm) samples; Laue patterns taken in 50 ps will monitor kinetics in these materials. Closer to physics, resonant terms that enhance X-ray cross-sections near absorption edges mean that a high brightness allows surface magnetic scattering to be used to study magnetic multilayers and other systems of industrial significance. Other new possibilities arise in elastic diffuse scattering, ultra-high resolution inelastic scattering, Bragg scattering of X-rays by the nucleus (a high brightness overcomes the fact that nuclear scattering is 10^8 times weaker than scattering from electrons), surface physics, and high-energy topography and scattering.

M.J. van der Wiel, Director of the FOM-Institute for Plasma Physics, Rijnhuizen, explained that **free-electron laser sources** are also now becoming highly significant to condensed-matter physicists because they offer tuneable radiation (both continuous and pulsed) in the infrared, and to lesser extent in the visible and ultraviolet. In Europe, FELIX (Rijnhuizen), the Compact FEL at Frascati, CLIO at Orsay, and S-DALINAC in Darmstadt are operating or close to operating as a group of user facilities unified to some extent under the EC initiatives.

Handling 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 structural 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 2000. 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)





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.

may still be operating after the year 2005. A major reactor project (PIK, St. Petersburg) remains uncertain and the 1500 M$US Advanced Neutron Source project in the US is unconfirmed. The optimum would be to have 2 or 3 HFR-equipped centres like the ILL in Grenoble and a network of national sources.

Based on operating experience with the IBR-2 high flux reactor in Russia, rapidly pulsed reactor sources compete technically with spallation sources but are uncompetitive when it comes to cost and perceived safety. H. Lengeler from CERN explained that four pulsed **neutron spallation sources** are now operating around the world and several are being built or are under study. The last category includes the regional Austron facility and the ambitious European Spallation Source with 30-times more proton power on the spallation target than today's leading spallation source (ISIS in the UK).. Clearly, coordinating the balance between these various levels and types of facilities 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 number of centres. But it also tries to maintain a friendly rivalry between centres as the physics goals are challenging. P. Wyder, the Director of the High Magnetic Field Laboratory in Grenoble, explained that the solution is to use *ad hoc* coordination at the laboratory level to minimize unnecessary duplication and to share expertise — an approach that stems from the small-science/small group culture. There are no immediate plans to change anything as things seem to work.

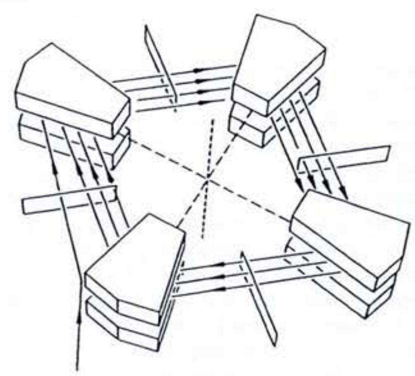
Consider, for example, high-field, steady-state hybrid magnets that were pioneered by his laboratory in building a 32 T unit. The technology has been taken up with Grenoble's help by new facilities in the US and Japan. The former, inaugurated on 1 October by the US Vice-President, is developing a 45 T hybrid in collaboration with MIT (it also offers the usual broad range of resistive magnets). The Japanese laboratory in Tsukuba will have the first operational next-generation hybrid (a 40 T unit) when it opens in 2-3 months. Grenoble has plans for a 45 T hybrid but it will take several years to complete as resources are scarce. Outside hybrids, there is a broadly based, loosely coordinated international programme: the US facility (in Florida) is collaborating with Los Alamos on very short, extremely high pulsed fields while most of Grenoble's upgrading efforts is going into a short pulse (0.1 s), 100 T unit for which design studies have been carried out with EC support. Europe is also taking the lead with a long-pulse ($\approx$ 1 s), 60 T installation being built in Amsterdam.

Exploring New Opportunities

The interest in exploiting new opportunities is demonstrated by the large (60%) and increasing percentage of muons being used as a probe in solid-state physics (the remainder is used for studying electroweak interactions and in atomic and molecular physics). C. Petitjean from the Paul Scherrer Institute (PSI) reported that **muon beams** are associated with four large facilities (PSI, TRIUMF, LAMPF, RAL) since they are invariably produced at medium-energy hadron accelerators.

The PSI and TRIUMF in Canada dominate with beams in six areas and five beams, respectively, and the PSI recently commissioned the world's best cloud muon channel offering a very high solid angle. Today's priorities are to boost luminosities, and to offer low energies (keV instead of MeV) and bunches for precision studies of surfaces and thin samples and the like. They call for the development of cooling devices and storage rings which present unusual challenges as the muon has a lifetime of only 2.2 μs.

Muon Storage Ring



Schematic illustration of a muon storage ring, one of the more challenging goals facing muon-beam facilities. According to J. Brewer [*Perspectives of Muon Science*, Eds: T. Yamazaki *et al.*, (Elsevier) 1992], surface muons would be injected into a sector focussing magnetic cyclotron field and decelerated by thin foils into a parking orbit. The muons would be electrically or magnetically extracted after accumulation for one muon lifetime (2.2 μs). The world's most powerful cyclotron at the PSI could offer beams with 10^2 positive muons per pulse, as compared with some 10^4 at 4 MeV in 20-80 ns pulses for ISIS. But it is a future European Spallation Source that would be an ideal candidate for a muon storage ring. Detailed studies are meanwhile required, notably of injection, extraction, beam dynamics, and limits to beam stacking.

FUSION

Global Projects are Not Easy

According to C. Maisonier, the Director of the European Commission's Fusion Programme, a commercial fusion reactor will be large (1 GW) and is at least 50 years away; it is also difficult to assess if it will be economic. With this in mind, he described how the EC programme (45% funded by the EC; 1700 staff) presents itself as a single body in international relations and integrates all joint European activities in fusion, ranging from participation in the International Thermonuclear Experimental Reactor (ITER) project, operation of the Joint European Torus (JET), and research carried out by national Associations. The 5600 M$US ITER **tokamak** is seen as the precursor to a demonstration reactor DEMO for the year 2025, and construction in 8-years could start in 1998. An optimized design (10000 seconds burn time, 1.5 GW fusion power, 6T toroidal field at the major radius of 8.25 m) was announced in December 1993.

Since agreement on a single structure could not be reached, the ITER protocol between its four partner countries specifies that the 1992-98 ITER design phase be done by an unwieldy set-up involving a joint central team and four home teams. It is also proving difficult to identify a site so there is a danger of "cost drift". This illustrates the difficulties encountered in negotiating global projects of a scale that "dictate" an international collaboration. The critical remaining technical issues, by contrast, seem clear-cut, namely the removal of burnt residues, steady-state operation, low activation and damage resistant materials, and remote maintenance.

Keeping Options Open

In Europe, operation of the JET torus, which is too small to induce ignition, with the correct D/T fuel is planned for 1996, and there is a possibility that JET will be extended until 1999 to test ITER components (specifically divertors). There have been efforts to even out differences in capabilities between the various national Associations, which are mainly engaged in long-term technology development and concept improvements aimed at DEMO. This philosophy helps ensure a sound base in the event of unforeseen difficulties with a major project such as ITER.

In aiming to keep other routes to fusion open, it will soon be decided if a new large **stellerator** in the Wendelstein series should be built in Germany (Europe already has three smaller stellerators and a new one is being built in Spain). The consideration of other reactor configurations was taken up by F. Troyon (Lausanne) who explained the difficulty in understanding plasma confinement and the empirical scaling laws upon which designs are based. He also stressed the importance of studying the various aspects of fusion using tailored devices.

The **inertial approach** to fusion has seen much less effort than magnetic confinement. After a series of studies and limited research programme carried out within a loose framework, R. Bock (GSI Darmstadt) believes that the time has come for a European study of a High Intensity Ignition Facility representing the logical next step (a dedicated 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 parameters. The US, meanwhile, plans to upgrade its large NOVA laser facility and is considering an ion-beam driven ignition facility based on different type of linac.

ASTRONOMY

Balancing New and Established

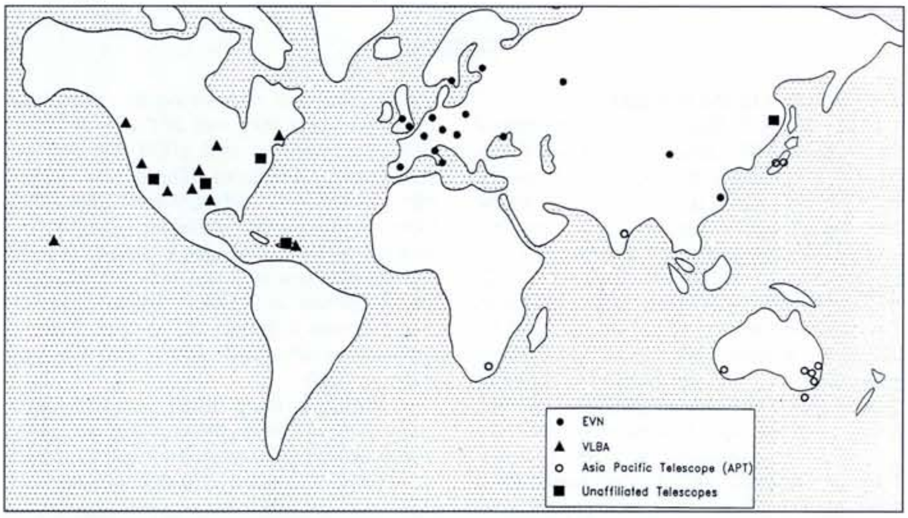
Turning to ground-based astronomical facilities, T.J.-L. Courvoisier from Geneva gave a remarkably concise review of much that has been achieved in increasing parameter space these past decades (spectral domain now extends over 15 decades, detector sensitivity increased by 100-times, spectral resolution increased by 10-times, angular resolution decreased from 1 to 10^{-4} arcsec, line resolution decreased from minutes to less than msec of arc). This has naturally led to unexpected observations and an increased intellectual challenge to solve several basic questions. His talk pinpointed 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 m^2 compared to 150 m^2 for the previous generation of 3.5-6 m devices) are starting to come on-line beginning with Keck-I last year. In the IR, one is now talking of detector arrays with 256 x 256 elements. In the **radio range**, one is looking at both antenna in space and evolutionary improvements to increase resolution, detection area, wavelength range, and long-baseline interferometry performance. Major projects under discussion include an array of up to 20 dishes, each of 40 m diameter, and an array of 50-100 high-quality 10 m antenna working at mm-wavelengths. Solar physics has plans for a 2.5 telescope (called LEST) and there is much interest in using balloon experiments in the dry, thin Antarctic atmosphere for the mm domain. A surprising new aspect has been the highly significant results obtained using massive sky surveys. With so much happening, and the scale increasing, its is hardly surprising 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-waves 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 about the year 2000) and Europe is to build VIRGO (first tests in 2000). They have similar levels of cost (about 80 MECU per device) and annual funding. G. Fontaine (In_2P_3/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 6 W (the target is 10 W), and mirrors have been ground to give the required 1-2 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.

Thierry Courvoisier, on the left, with Claude Joseph who chaired the local organizing committee.

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.



SPACE SCIENCE AND ASTROPHYSICS

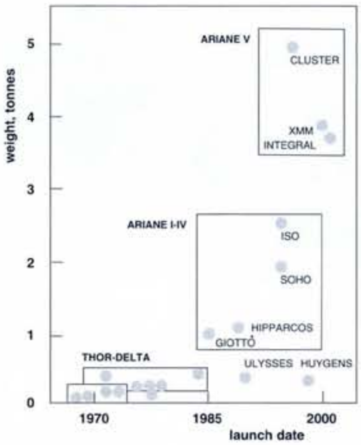
Technology ..... Offers Opportunities

By describing the proposal to the European Space Agency (ESA) for an extremely elegant space-base 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 as a possible Cornerstone mission — see page 184). LISA envisages a considerable increase in sensitivity using two 5 x 10^6 km long arms that cartwheel in space in a complex orbit (an ellipse inclined to the elliptic) about the Sun, some 20% behind the Earth. As such it breaks through the "gravity-wall limit" at 1 Hz imposed on earth-based detectors and it aims to exceed by several orders of magnitude what can be done (and is being done to some extent) by tracking spacecraft. It is in fact designed to monitor "guaranteed" gravity wave sources, notably compact binaries in our own galaxy.

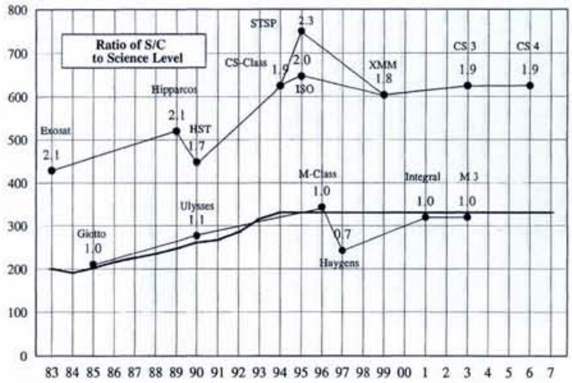
... But More is Needed to Extend Limits

Handling complex technology in the extremely industrial world of tendered equipment has some drawbacks. However, R.M. Bonnet, Director of ESA's Science Programme, gave statistics assuring the audience that this has not prevented facilities from being delivered successfully. Europe's space science programme is significant in that it currently spends 488 MECU each year (largely fixed for 5 years, and "revisited" every 3 years) compared with 1444 MECU (and decreasing) for the US and 168 MECU (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 and resolution, and have not limited their ambitions. So the statistics (see figures) suggest we may be

Gérard Fontaine, on the left, and Klaus Danzmann spoke about gravity wave interferometers.



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.



"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 co-operation to generate critical masses.

Structures to Handle Facilities' Growth

Astroparticle physics has been characterised 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 Kamiokande 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.

1994 EPS Large Facilities in Physics Conference

ROUND-TABLE DISCUSSIONS

Three round-table discussions were held during the *1994 EPS Large Facilities in Physics Conference.*

Large and Small Science
Challenges and Benefits of Large Facilities
Selection Procedures & Priority Assessment for Future Large Facilities

ROUND-TABLE: *Large and Small Science*

Promoting Opportunities Together

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 must be encouraged. 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 organization and increased size and internationalism we are now dealing with a new way to do science, and it is this that one should look at.

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 Kroó, EPS President and Director of the Insti-

PANELISTS

K.H. Chang, *FOM, Utrecht*
J.-M. Gago, *LIP, Lisbon*
C. Jarlskog, *Lund* (Chair.)
A. Santoro, *CBPF, Rio di Janeiro*
P. Wyder, *MPI-CNRS, Grenoble*
Y. Yamaguchi, *IUPAP, Tokyo*