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Round Table Synthesis Report

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Executive Summary

The European Space Agency (ESA) has been conducting a study over the past two years to examine what impact commercial, social, political, cultural and economic issues might have on space activities in the next 25 years or so. This on-going activity, known as 'Space 2020', has attempted to provide a programme-independent view of the possibilities and constraints for the European space sector in general, and ESA in particular, by interacting with specialists and experts from all major disciplines to derive a strategic assessment of the future of European space activities.

Space 2020 included a Round Table organised at ESTEC, Noordwijk (NL) at the end of June 1995. Specially invited participants presented position papers for discussion in four areas selected for their relevance to Space 2020. These areas were:

- concepts for cost reduction
- new services and potential synergies
- trends in research and development
- the role of ESA and international cooperation.

From these topics and the ensuing discussions, a number of important considerations for the future of European space emerged. Although the study was in principle looking at the world in the year 2020, in practice this longer term perspective received relatively little attention during the Round Table because it was felt that defining a suitable strategy (or 'road map') for achieving a secure future for Europe in space was more important than examining the potential social, political and economic scenarios themselves at that time.

The space sector today is going through a transition period and gradually settling into a mature scientific and industrial sector where basic technologies exist within industry as well as the competences to use these technologies, where market forces increasingly determine the developments, which are influenced by many players, and where public budgets remain constant or even diminish.

Such a situation implies that private investments will more and more become the primary method for financing application and commercially driven space activities. New rules will therefore come into play which space agencies will need to support; for instance, new activities may possibly only be carried out when done in conjunction with an operational entity. Thus the role of space agencies will change and the public funding will thus serve more as a catalyst to industry rather than directly financing commercially-driven space activities, although scientific and exploratory activities will still be best undertaken and managed through cooperating supranational space agencies. This will involve a new set of relationships between space agencies and industry, with the agencies providing financial incentives and absorbing risks for the pre-competitive part of new research and development.

In turn, space agencies may become even more involved with the active promotion of emerging and potential applications for space use. It is not only a question of what space can bring to the public or industry at large, but also what can be brought to the space sector by these communities. Furthermore, synergy (or lack of it) between military and civilian developments and activities (space as well as non-space) will very much determine the future structure in Europe as well as elsewhere.

As far as Europe is concerned, the European Union (EU) is actively involved in establishing industrial policies in all areas of life on a pan-European level. Thus any European space policy must necessarily be drawn up in the light of prevailing relevant EU policies regarding operational needs, competition, technology development, market growth and penetration of global markets. Cost reduction is the most important single factor in terms of global competitiveness for European industry and thus has to be supported wherever appropriate. The move to cost reduction, and hence greater efficiency, is something ESA is embracing and this can be fostered, in keeping with EU policies, by a consistent and common policy involving all partners (ESA, service providers, industry, users).

Such a policy clearly consists of cooperation, though the dualism between cooperation and competition on a global scale will remain on the political and industrial agenda for the foreseeable future. The decision on whether to compete or cooperate will be based purely on economic and/or strategic needs, and both will be in evidence between the same companies and organisations at the same time. This will not be a bad thing, however, as competitive forces on a global basis are putting pressure on the European space industry to reduce costs.

A major contribution to improving the situation with industry would be if ESA could shorten its traditional study phases, accelerate technology transfer and provide more mission opportunities. It would be helpful in this respect if ESA was to cooperate with industry and universities to develop technologies for low-cost missions. This would entail, of course, ESA providing a long-term perspective to its industrial and academic partners and adopting a systems-engineering approach to reduce life-cycle costs.

The above-mentioned evolution of the space sector will almost certainly necessitate a restructuring of the space industry, with company mergers, increased responsibilities, avoidance of duplicated efforts, higher efficiencies, leaner and meaner work forces, greater information exchange, and a reduction in the number of layers of subcontractors. More interconnectivity and intercooperation between disciplines (such as telecommunications, navigation, remote sensing, etc.) would provide major benefits, as would greater synergy with other non-space industries and sectors. There is a clear need for strategic partnerships in order to survive in a global context, and such partnerships require a commitment beyond commercial interests.

Markets (e.g. telecommmunication, earth observation) are continually expanding and new players are continuously appearing on the scene. The markets need new technologies, financing and cooperation in order to generate the benefits which would occur from better, wider and cheaper access to space-based services. Global trends towards deregulation and open-border competition are generating new opportunities and threats which require new initiatives. Technology trends and breakthroughs and R&D as a driver are elements which have to be considered in conjunction with industry and academia.

Substantial reduction of launch costs by spacecraft miniaturisation and the development of cheaper launchers will be a key factor for competitiveness. Nevertheless, the key issue is whether the total life-cycle cost of such a system, and particularly the high R&D costs, will ever reach the economic break-even point. Micro/nano technologies may become increasingly important in this respect in the long term.

A replacement of the traditional linear process of innovation (i.e. 'techno-push') by a dynamic, interactive model characterised by the 'demand-pull' approach is needed. This will have an impact on the way in which ESA initiates its programmes, particularly its technology programme. Rapid reactions to demand-driven requirements are becoming a prerequisite for success.

1 Introduction

ESA's 'Space 2020' initiative attempts to assess today's situation in terms of tomorrow's potential developments within the space sector, in order to support a strategic long-term programme. The European space sector and ESA are part of a complex network of socio-economic factors. It is expected that the structural changes, on a global as well as on a continental scale, which are most likely to occur during the next few decades will strongly affect the future of the space sector in general, and thus the role of ESA.

The Scenarios

In the first phase of the Space 2020 study, two important scenarios were selected as reference models for the time horizon chosen: the 'Greater Europe Scenario' and the 'Little Europe Scenario'. The Greater Europe Scenario held that, around the end of the decade, the European Union would in principle have monetary union, convergence of economic policies, an integrated defence system, and a common foreign policy. The Little Europe Scenario, on the other hand, held that no real progress towards European integration was expected up to the end of the decade, particularly as far as monetary union and the convergence of foreign and defence policies were concerned. Regardless of which of these two scenarios proves to reflect more accurately the situation prevailing by the year 2020, it is expected that the major challenges for the European space sector are likely to stem from the mounting needs for commercial services in the most dynamic regions of the world.

The Round Table

The second phase of the study resulted in the Space 2020 Round Table, held on 28/29 June 1995 at ESTEC, which was organised jointly by ESA's Technical Directorate and Associate Directorate for Strategy, Planning and International Policy, as an interactive workshop.

The participants at the Round Table presented position papers for discussion in four selected areas of relevance to the Space 2020 study, covering potential for cost reduction, new services and potential synergies, trends in research and development and the role of ESA and international cooperation.

ESA's Space 2020 Round Table endeavoured to discuss a programme-independent view of the possibilities and constraints for the European space sector and for ESA in particular, by interacting with external participants from all areas of the space sector in order to derive a strategic assessment. This independent view has a great value when analysing the complex networks of factors influencing future prospects for the space sector.

The outcome of the Space 2020 Round Table constitutes both a projection and an evaluation of potential developments of space activities in general, as well as of ESA itself, with the objective of anticipating and preparing the possible future infrastructures of a dynamic and efficient Agency with a competitive European industrial base.

This document contains a synthesis and the conclusions of the Round Table and is based on the individual presentations of the participants and the panel reports, from the four selected areas.

This 'Space 2020' synthesis will be elaborated further by ESA. Specific recommendations and follow-on actions will be defined for further work in collaboration with representatives of Round Table participants.

2 Cost-Reduction Potential

General

Cost-reduction concepts for space systems should be seen as contributions to improving the overall end-to-end full life-cycle cost/benefit ratio. Nevertheless, the Round Table focused primarily on the space-segment elements, i.e. the satellites and their transportation to orbit. This perception and limitation should be corrected by the future activities.

The world space industry today is suffering from a decrease in R&D budgets. On the other hand, market indicators consistently point to a potential expansion of the demand for satellites and space launch systems in the medium term. It is important not to miss the opportunity to exploit this market demand, and there is a need to try and force costs downward, in order to foster an even greater expansion of the market (concept of the 'virtuous spiral').

Strategies which are particularly appealing, since they are potentially valid in the near term, are those which entail policy and organization changes (at the level of industry, agencies, and government).

A re-structuring of the European space industry is likely to be a major requirement in order to achieve the level of competitiveness required for survival in a competitive market. Re-structuring would encompass widespread introduction of vertical integration (by cooperation and/or acquisitions), the assumption of more extended responsibilities (and associated risks) by industry, the suppression of duplications and redundant capabilities, greater efficiency in project-team organisation, reduction of artificial layers at subsystem level and of the over-extended European subcontractor network.

Policy changes to be adopted concern the need to replace the 'risk avoidance' practice with a 'risk management' culture, thereby accepting (and tolerating) failures within a space programme, in order to be able to make use of the most appropriate technologies (e.g. advanced micro-technologies, commercial quality standards). Relaxations of the highly structured industrial political constraints which characterise the European space market are also strongly advocated. ESA's geographical-return rules are a candidate for review, as are other decisional waypoints imposed at national and European level by the current political, administrative, and industrial structures.

Competitiveness of European industry in a scenario of shrinking government funding but expanding commercial markets, should be based primarily on the achievement of technological excellence, rather than on the attempt to reduce the cost of labour – an area in which the developing countries are likely to maintain the upper edge. New application fields and new, advanced technologies which should be primarily targeted for this strategy can be short-listed at this stage, with particular emphasis on the exploitation of technologies which are state-of-the-art outside the space sector (e.g. data processing).

Economies of scale and scope (series manufacturing of spacecraft or re-utilisation of modular spacecraft elements and buses), would offer moderate savings (10–25%), and thus should be sought as a helping factor in the overall cost reduction of space missions.

Transportation to orbit will be a key element in allowing space mission costs to be forced downward. Market perspectives envisage the maintenance of a routine market for conventional medium-size and large expendable launchers, within an environment of increased commercial competition. This will be played mostly on factors such as system availability, observance of schedule, flexibility, quality of service and reliability. However, in terms of costs, only moderate (15–20%) reductions can be expected from conventional launchers. In the emerging field of small launchers, significant reductions in the cost per kg to orbit are not expected either; however, small launchers will be best tuned to the needs of future small satellites with very short procurement cycles.

Drastic reductions in the cost of access to space can only be achieved with new launch systems (such as re-usable single stage-to-orbit systems). However, the very high initial development costs for these systems (primarily due to the R&D effort required) make it impossible to judge with confidence if the market response (in particular, the development of new market sectors) will offset the investment required.

A new development approach is required at satellite level in order to reduce costs. This means breaking free of conventional schemes based on the demand for minimum risk and maximum performance, with emphasis on high standards and, consequently, on high costs and long schedules. Small satellite programmes appear to be an ideal field in which to test new development approaches, thanks to the lower technical risk, smaller budget, and shorter programme duration involved. Lessons learnt from small satellite programmes should be scaled up for application to larger spacecraft and missions. Furthermore, the exploitation of organisational structures and expertise from the space and earth-science communities, involved as end users in the development of spacecraft instruments, is regarded as highly beneficial when applied to the development of the payload and the end-to-end system optimisation.

Most of these conclusions are well in line with the on-going ESA initiatives, such as internal and external reviews with the aim of improving the cost-effectiveness of its own operations, with initiatives in the field of small-mission opportunities, as well as studies of future launchers, satellite concepts, architectures, technologies, and services.

Strategies

Changes in Policy and Organisation

Various strategies to initiate a downward cost spiral have been identified and discussed. Several of them are centred around:

- a re-structuring of programme and industrial/customer organisation, and
- a relaxation of industrial and political constraints.

These strategies appear particularly appealing, since they are potentially applicable in the near term and, generally speaking, do not require major investments.

A potentially wide-ranging re-structuring of programme and industrial/customer relationships and organisations is required to encompass the strategies indicated in Table 1.

Some of these new approaches do require a change from the current practice of 'risk avoidance', generated by the high cost of a mission, to a more flexible culture based on 'risk management', in which a given number of failures are to be expected (and tolerated) within space programmes in order to allow a reduction in costs.

Re-structuring of European industry to face the challenge is expected to include a shift from the current high level of sub-contractorship (50% in Europe versus 30% in the USA). Only five major Prime Contractors are active at spacecraft level in Europe nowadays, out of more than 350 European companies involved in the satellite industry. A process of integration and the establishment of partnerships is already taking place in this domain.

A possible relaxation and/or modification of industrial-political constraints in European space (at industry, Agency and government level) is widely advocated. ESA's geographical-return rules are perceived as a candidate for review. Quite apart from the ESA level, complex structures exist in Europe which impose numerous decision waypoints at national and European level (e.g. in the telecommunications field). At national level, several Ministries, civil service departments, government agencies, industries and interest groups are involved in defining priorities and allocating budgets and investments, thus creating a degree of confusion and inefficiency.

Table 1. Restructuring potential

Industry-Customer Relationship	Industrial Organisation Restructuring
New working procedures and methods (greater commitment by final users, higher efficiency in operations, more synergy, integrated customer/industry teams for better communication exchange, integration of end-user/payload representatives into project teams)	Increased involvement of industry in all aspects of business through the widespread introduction of vertical integration (found to be not sufficiently applied within European industry) by cooperation and/or acquisitions
Attribution of more extended and comprehensive programme responsibilities to industry (including external interfaces), as well as a share of the associated risk	Avoidance of duplication in investments, there being an obvious overcapacity in Europe, with current trends to increase, rather than to reduce, such capacity
Adoption of appropriate technologies (e.g. commercial quality standards, wherever possible)	Improvement in product conception at Prime level, with fewer artificial layers at subsystem level (and consequently a rationalisation and consolidation of the Sub-Contractor network)
Fewer payloads and targets for the same spacecraft	Smaller project teams, shorter programme durations, with less tolerance of slippage

A culture based on the exploitation of 'lessons learnt' should be enforced in ESA and industry. The review and analysis of past programmes should be part of routine project activities, becoming a part of project-team and project-manager training schemes, with benefits to the overall cost- and schedule-control process.

ESA has become aware of several of the above organisational and procedural issues in the past few years, and has started a process of internal and external reviews (with the aim of achieving greater cost-effectiveness). These reviews include the Director General's internal review of the Agency carried out in 1994, a Price Waterhouse study of the internal cost charging system, and an Andersen Consulting review of the Agency's resources, organisation and procedures.

Competitiveness through Technological Excellence

Survival of the European space industry and, more generally, of the concentration of the world GNP in the more technologically oriented countries (Europe as well as the USA and Japan), will be possible only by achieving control over new growing markets, possibly through intense competition. The key to competitiveness will be technological excellence rather than the cost of labour, in which developing countries are likely to maintain the upper edge.

This requires a sound selection of advanced programmes in both science and applications. New front-line applications will be found for several of the most promising space domains, in which significant cost reductions can be achieved by new, advanced technologies. The most promising of such applications, and the related technological areas, include those listed in Table 2.

Table 2. New applications and related technological areas

New Applications	Most Promising Technological Areas						
	Autonomy and Operations	On-Board Computing	Microsensors, Micro-instruments, Microelectro-mechanical Systems (MEMS)	Power Systems	Propulsion Systems	Materials and Structures	Design and Manufacturing
Multimedia		X	X				X
Space Navigation Systems	X	X	X	X		X	X
Earth Observation	X	X	X	X		X	X
New Transportation Systems			X	X	X	X	X
Mobile Telecommunications	X	X	X	X		X	X

The widespread use of existing technologies which are state-of-the-art outside the space sector (e.g. computing) is regarded as a potential breakthrough. On the other hand, some of the identified new, promising technologies do offer commercial spin-off in non-space applications.

Economies of Scale and Scope

Economies of scale and scope are expected to be achieved in programmes capable of the (limited) series manufacturing of a bus or of complete spacecraft. Past and present programmes of this type include, for example, HS-601, Globalstar, Iridium, GPS, Tiros and Meteosat. Economies of scale may be achieved:

- on non-recurring costs, when development costs can be amortized over a wide production base, thus achieving greatly reduced unit prices, or when several satellites are produced within a 'family', re-using the basic design and saving on development time and cost (e.g. by the adoption of a modular spacecraft bus) or by increased use of standardised units
- on recurring costs, by exploiting the 'learning effect' in the production and procurement of components and subsystems.

Estimates of the actual benefit deriving from economies of scale are expected to vary between 10 and 25%, depending on the cost model used (a rather limited database exists in the field of series manufacturing for space). In general, although economy of scale is acknowledged as a helping factor in reducing cost, it has also to be coupled to other strategies (such as those listed above) in order to yield significant results.

Satellites

Satellite Development Approach

One of the most critical cost contributors is the development approach, for which a standard pattern has evolved over the last few decades for the European institutional programmes. This is aimed primarily at achieving low risk and high performance by imposing very high standards, although at the expense of high costs and long programme durations. This situation stems directly from several factors, including the complexity of space systems, their intrinsic high cost and the natural trend towards growing bureaucracy. This development approach is embedded in most of the standards, methods and processes existing in the space agencies, as well as in industry, and represents a strong cultural bias which can hardly be removed in the frame of conventional programmes.

An evolution towards a new development approach is needed, involving 'cultural changes' in various domains. Such an approach would combine:

- customer/industry relationships (establishment of integrated teams)
- industrial organisation (autonomous and fully responsible core project team, 'lean management' approach)
- product-assurance standards, procurement approach (commercial PA standards, 'lean' formal documentation, procurement of off-the-shelf equipment, enforced competition in equipment procurement)
- development and engineering approaches (integrated flow from conception to in-orbit operations, design-to-cost, new standards and new margin policy from in-orbit experience feedback).

Small satellites, currently blossoming in the USA and only just emerging in Europe, offer an opportunity to test radically new development approaches. Small satellites are an ideal testbed for techniques which may eventually be extended to larger spacecraft, because:

- they are less complex systems, thus with lower technical risk
- they involve smaller budgets (few tens of MECU range), thus lower financial investment risk
- programmes are of shorter duration (typically 2 years to launch), thus offering rapid feedback on innovations at either development or product level.

The implementation of new development approaches on small satellites, with a clear mandate of innovation, and within the frame of lean experimental organisational structures not hampered by conventional administrative rules, may be considered as an important programme outcome per se. It may be expected that, even though the experience acquired on small satellites will not be fully directly transferable to larger ones, the return for the latter will still be invaluable with a concrete hands-on experience to facilitate the necessary cultural changes.

Space Science and Earth-Observation Research Missions

Table 3 shows the synergy between the space science (astronomy) and earth-observation fields, especially when basic scientific missions are compared. The evolution of earth-observation missions towards commercial projects includes a new economic dimension.

In the particular case of a space-science mission, or an earth-observation research mission, scientists (as the end users) require a low-risk satellite bus, launch, operations, and a framework of expertise in which to work. On the other hand, they have to provide a scientific return commensurate with the cost, and guarantee adequate

Table 3. Funding sources, cost reduction potentials and return on investment for space science and earth observation missions

	Astronomy Space Science	Earth Observation Scientific	Operational	Commercial
Funding for Platform	Government	Government	Government --> Private	Private
Funding for Payload	Government	Government	Government --> Private	Private
Cost-Reduction Techniques for Platform	Miniaturisation Re-use of designs	Miniaturisation Recurrence Small Series	Miniaturisation Recurrence Medium Series	Miniaturisation Recurrence Large Series
Cost-Reduction Techniques for Payload	Use of Academia/ Research Labs.	Use of Academia/ Research Labs.	Miniaturisation Recurrence Medium Series	Miniaturisation Recurrence Large Series
Return on Investment	N/A	Indirect	Indirect/Direct	Feedback from Market

reliability of the instruments. In this context, it is noteworthy that the development of the scientific instruments is usually cheaper than the development of the satellite bus. This is perhaps surprising, since the scientific instrumentation is so often the technically novel, complex and challenging part. The reasons for this include the cheaper access to high-quality labour provided by academia, more relaxed engineering standards, and less administrative and bureaucratic overheads.

Significant cost reduction for conventional space-science missions should be possible without changing the number of missions undertaken, or introducing any major changes in Agency management or procurement policies (e.g. juste retour principle). Specific measures for cost reduction to be taken at spacecraft level, as lessons learnt from the scientific-payload development approach, are essentially:

- greater competition for equipment procurement
- increased participation by scientists (as end users) in the early project phases
- release of contingency funding to be traded-off versus the option of reducing the specified performance
- utilisation of scientific institutes in a flexible and effective way (e.g. for ground processing, and in subsystem areas closely interfacing with payloads)
- use of a common bus for several projects.

Further possibilities for savings in science missions can be identified: for example, using a small-mission approach or by changes to general agency procedures, as described in the preceding sections.

Transportation

Status and Short-Term Trends

The space-transportation scenario beyond 1995 is characterised by a wider 'offer' and 'demand' situation. The spectrum of new launch capabilities (market 'offer') includes a new US launcher, on which a decision is expected soon, the beginning of the Ariane-5 operational phase, and new competition at global level by the entry into the market of Russia and China. Increased competition among these new capabilities is forecast in the short term, driven primarily by: launcher availability, observance of the agreed schedule, flexibility, quality of service, reliability, and price.

New needs (market 'demand') in space transportation are being created by various factors, such as the liberalisation, regionalisation, and internationalisation of telecommunications, and the coming of age of new TV, data and voice applications. These needs act as potential boosters of the navigation and communications satellite market with, in addition, the new market entry of small satellite missions. This will lead to an increase in the short-term launcher demand (with a potential peak of 90 satellites over a three-year period).

Medium- and Long-Term Prospects for Conventional Launchers

The medium-term evolution foresees a classical stabilised (mature) market, dominated by several large national, regional and international operators equipped with powerful satellite systems. The setting up of LEO, MEO and GEO constellations will generate medium and large launcher activity (including a high demand for the launching of 'spares'), on the basis of commercial negotiations in long-term programmes, with an increase in the responsibilities of the launch authority (including guarantee of success).

The long-term evolution foresees a routine market for the maintenance of existing networks, the sector being limited to a few large information operators (plus scientific and remote sensing) and to satellite transport services. This will be coupled to emerging markets such as the initial operations of space platforms, new man-in-space activities, and the development of European military space applications. In this market context, the transportation services will be characterised by:
- a sharing of R&D activities at international level (Europe/USA, 'Greater Europe'), including an internationalisation of industry
- a decrease in production and life-cycle costs (decrease in parallel with satellite cost decrease)
- the adaptation of launchers to commercial demands, by means of market surveys and an increased interaction between R&D, market and operations
- the development of a capability for rapid response to evolving market demands
- launcher systems with higher reliabilities and longer satellite lifetimes
- an increased responsibility for launch operators (in terms of guarantee of success, i.e. system quality and reliability, and therefore lower insurance costs).

However, significant cost reductions will be difficult to achieve in the domain of conventional medium and large launchers. Current cost levels for such systems are around 7000 US $ per kg to LEO. These costs levelled off in the 1980s after several years of a constantly decreasing trend. Nowadays, substantially stable price levels are to be expected (from USA and Europe), with overall cost reductions of no better than 15–20%.

Several small launcher options are currently emerging, including a few European developments (e.g. Capricornio, Vega, ESL), with capabilities in the 100–1000 kg payload to polar orbit range. Although the cost per kg may not be substantially lowered by such launch systems, they are much better tuned to emerging small mission opportunities (science, earth observation, communications) in the 200–600 kg satellite launch mass range. In addition, cooperative agreements and industrial joint ventures with Russia have recently surfaced in the small launcher field (e.g. Diana/Burlak, Kosmos).

Future Launcher Systems

In the field of space-transportation systems, the current technology is basically the one derived in the 1960s, and one on which the main efforts have been directed more towards optimisation and cost reduction rather than towards achieving an effective breakthrough. Major changes are expected in this area within industry, agencies and governments.

The cost structure inherent in a launch system based on expendable multistage rockets limits the range of space applications to those which have 'data' as the end product (science, remote sensing, navigation, communications), due to the high costs involved. Further markets such as manufacturing, energy generation and even tourism (generally speaking, applications requiring re-entry from space) are not viable at current transportation cost levels. Opening up new markets requires drastic cost reductions via fundamental changes in both launch systems and in-orbit services.

The scope for cost reduction with expendable launchers is limited, as highlighted above. A potential route to major cost reductions is the development of airliner-like reusable launchers. Single Stage-to-Orbit (SSTO) systems have been shown to be technically viable by studies conducted in the 1980s. Such vehicles are cost-reduction candidates. The key issue is whether the total life-cycle costs of such systems (and in particular the exceedingly high R&D costs) will be offset by the market demand. According to one hypothesis, the break-even point with Ariane-5 may occur already at the comparatively low rate of 15 launches per year.

Launchers as Elements of the Space Infrastructure

Currently there are two methods of supporting a system in LEO: dedicated robotic satellites and manned platforms. Analysis shows bottom-line costs of supporting activity in either infrastructure to be comparable, but with a different cost structure. Manned systems require more mass in orbit and thus have higher launch costs, but with greater re-use of designs and equipment. If launch costs decrease, manned infrastructure gains a higher benefit.

Whilst for launch systems the drive is for optimised high-technology approaches, trading high acquisition costs for lower operating costs, the opposite would be true for payloads, in which the drive is for simple and technically crude approaches that minimise acquisition costs. The optimum approach for low acquisition costs is a design utilising cheap manufacturing techniques and re-use of proven components.

However, even with low launch costs, unmanned spacecraft will still represent large investments and large overall system costs, providing a drive towards high-reliability approaches. Therefore there is a limit to the level of simplicity and crudeness that an unmanned satellite can accept, and thus a limit to the reductions in acquisition costs.

On the other hand, manned systems offer the approach of reliability which is traded off against human intervention capability. Furthermore, human control of a system might reduce complexity, and thus overall system acquisition costs. The combination of launch-cost reduction and greater benefit from technology advancement could enable manned spaceflight to achieve cost reductions significantly larger than unmanned systems (one order of magnitude). This would reduce the cost of LEO activity from the present range of 2–200 M US $ per payload to 0.2–20 M US $ per payload. But even with this option, manned space flight 'survival requirements' (including return requirements) will remain essential, so that safety becomes the cost driver even for 'bare bone' manned systems.

3. New Services and Potential Synergies

General

The major fields of activity, such as earth resources, telecommunications, telemedicine, navigation, meteorology, etc., rather than existing as separate disciplines, would all benefit from a certain degree of interconnectivity and inter-cooperation since there are many infrastructure elements common to all areas. As part of this, organisations should pull in the same direction for the benefit of users and industry as a whole. To this end, future operators as well as industry should be involved to some extent in the decision-making processes of space agencies at an earlier stage. This might involve implementing a better partnership/relationship with industry in all fields.

Developing countries should receive more attention, since the developing nations of today are the social, cultural and business partners of tomorrow, as well as future markets. An active contribution is required to support developing countries and this could be in the form of funds, assistance, services or training, among other possibilities. An emphasis on education (particularly tele-education) and training for such developing regions is considered especially useful, as is more emphasis on educating the general public and making it more aware of space activities and benefits. The ESA membership should be expanded and the problems posed by the 'fair return' policy could perhaps be solved by making all programmes mandatory. Developing non-traditional sources of income would also assist in this respect.

It is recognised that there is good scope for synergy with several other industries, notably the aircraft and automobile industries, as well as other sectors such as health and medicine, and military/defence. It should be noted that there is a need for strategic partnerships in order to survive globally, and that partnerships require a commitment beyond immediate commercial interests. It is considered that complementing rather than competing leads to synergy, and that space agencies and space companies should accept partnerships in large projects – whatever the discipline – even if there is a low space involvement. Getting in on the ground floor would mean that the space sector would not be forgotten and would at least have some involvement, which could lead to more. It is also pointed out that synergy is aided by standards and the integration of common tools, both within the space industry itself and with other non-space industries.

The 'Information Society' is fast becoming a reality, with one of the major components being the information superhighway. Broadband networks are seen as an important part of this future, and it is noted that there is a competitive environment between cable, telecommunication and satellite companies to reach the end users. A global information infrastructure is seen as a major goal to complement North America and Japan, but it is vital to have new services to meet social and market demands in Europe, in order to stave off the American challenge.

Remote sensing spans a wide range of inter-related market segments, with the evolution in each segment impacting on new services and synergies. It is believed that there are potential applications on the horizon which are awaiting solutions and that commercial markets would develop. A larger user-base (i.e. market) could be created through raised awareness of earth-observation programmes and products.

Several improvements in the area of remote sensing are necessary. There is a need for higher spatial, spectral and temporal resolutions, as well as a demand for more and better data and easier and faster access to it. It would be necessary to create new systems (space and ground) and products better adapted to user needs, and to reduce the gap between technological push and market pull. Synergies between the civil and military demands will benefit the creation of such systems. Once operation is demonstrated, financing via the market becomes more likely. Adequate system performance and affordability should put remote sensing at every individual's fingertip's all across the world. It is considered vital that there be more and better cooperation between international earth observation entities, and that the needs of developing countries are supported.

Of particular note is the fact that most initiatives in the telecommunications field appear to be coming from the USA and the question has to be asked: where is Europe in all this? It is clear that there are many future developments of interest, including wideband, two-way, end-user multimedia communications and global, portable, personal mobile communications. New orbits and frequencies are required and integrated and interconnected networks are necessary, as are cheaper terminals to access the growing range of tailored space communication services.

There is no doubt that the market is expanding and there is a rapid proliferation of new entries and players coming onto the scene. It is evident that the market requires new technologies, financing and coordination, and there would be benefits from better, wider and cheaper access to communication links in general. ESA should take bold new initiatives in the field and should pursue the opportunities being presented by the global trends towards deregulation and open-border competition, in order to counter threats from elsewhere.

Whilst there are several areas under discussion which would benefit from a space presence (e.g. monitoring potentially dangerous civil and military activities and monitoring debris and close encounters), what is really required is a complete rethink of the traditional approaches. To this end, it would be useful to supplement or even replace traditional approaches to space use with completely fresh ideas, as well as conceiving projects appealing to the public imagination.

Keys for successful synergies include highly innovative programmes in both the scientific and technological areas, with an early identification of applications. A strong and clear involvement from partners is necessary, and implementation of joint-ventures is required from the very beginning of project rather than just at a later stage. It is recommended that the space community should accept partnerships in (health and other) projects even when there is a low space involvement, so as to get a toe in the door and not be left behind or even out of any potential new areas.

As far as the health sector is concerned, it is felt that there could be improved cooperative and complementary approaches between the different aspects of space life sciences (e.g. basic research, space medicine and applications). Synergies should be promoted between space and health research by developing user-driven definition of programmes. Industry would need to be involved in joint ventures (for the sharing of costs and development of spin-offs) and the market for use of space would need to be developed further.

Already, tele-medicine and tele-health projects are showing what could be done using space communications and tele-science as an added-value component. There is already synergy in these areas with the military. The medical and health sector would like to see low-cost communications available for tele-medicine, e.g. low-bandwidth cellular mobile links, near-real-time communication being good enough.

The high cost and difficulty of access to space appears to be a significant impediment to the development of new space business. Low-cost access to space would enable new applications on a significant scale, including the non-space technology markets.

Synergistic benefits may by their very nature be unpredictable, and designing a project for 'foreseeable synergies' may simply increase costs without benefit to the primary aim. Synergistic effects are thus not the principal reason for investment in low-cost launch vehicles, but are instead part of the total negotiating package and should come out of a project naturally. This is not to say that when designing a project one cannot look outside for synergy, commonality, re-use, launcher versatility and the introduction of commercial standards. Synergies are possible – and desirable in the interests of saving development time, money and effort – in structural design, hardware prototyping, manufacturing methods and tools, common avionics, integrated data and the use of simulation tools and many other areas. CATIA (Computer Aided Three-dimensional Interactive Application), for instance, is extensively used throughout the aircraft and car industries, but is not yet used to any great extent in satellite development.

Table 4. Synergy between space and other sectors

	Military	Aircraft	Automobile	Offshore	Shipbuilding	Nuclear	Other Space
Dual-use of facilities	High	Medium	Low	Medium	Low	Low	High
Procurement	High	High	Low	Medium	Low	Low	High
Common technologies and materials	High	High	Medium	High	Low	Medium	High
Workflow, procedures and systems engineering	Low to medium	High	High	Medium	Medium	Low	High
Life-support systems	Low	High	Low	High	Low	Low	High
Joint development of new applications, materials and products	High	High	Medium	High	Low	Medium	High
Marketing, promotion, public awareness	Low	High	High	Low	Low	Low	Low
Basic R&D	High	High	Medium	High	Low	Medium	High
Manufacturing	Medium	High	High	High	Low	Low	High
Fleet management and operation	Medium	High	High	Medium	Low	Low	High

Table 4 shows the potential for synergy in various areas between the space sector and other industrial sectors. In several instances (e.g. marketing, promotion and public awareness), it indicates how the space sector could learn from the other sectors.

Possible synergies between the civil and military space activities have been one of the general themes of potentially high relevance for ESA's future, and have now been under internal study by the Executive for more than a year. It can be observed that in the USA a strong effort to achieve coordination between several space-related civil agencies (NASA, NOAA) and military space organisations of the three services under DOD leadership is being made in response to US Government instructions. Although European military space activities appear much more modest than in the USA, there is potentially considerable parallel effort and expense in national and ESA space development programmes and in diverse European military space programmes. The risk of duplication of space technology and system development, and of double financing of the same or very similar efforts in European space industry will increase in the future, as European and national defence institutions apply more space technology for military defence and verification purposes. Some constructive thinking on these issues appears necessary.

Information Highways

Many new space-based services designed to enhance the quality of life need to be injected into a scenario where present-day communications and media/entertainment industries are merged in the forthcoming multimedia revolution. New services, therefore, will be part of a decentralised broadband telecommunications network which integrates the Information Society and space in terms of access via future Internet/WWW systems through low-cost ground feeder link stations to satellite links. New services for which the role of space can be primary with respect to wired and tele-education networks include tele-medicine, tele-working, tele-entertainment and tele-banking. The key to improving satellite penetration for such services lies in reducing the size and cost of user terminals, and thus moving to portable and mobile devices. The impact of advanced communications on economic growth in Europe could be as high as 6% GNP (285 BECU in monetary terms) under an accelerated scenario. Thus, the introduction of broadband networks would translate into substantial benefits for the economy.

The Information Society is faced by the two-fold challenge of social and market needs, with the driving forces being society itself and the market. One of the purposes of the future Information Society is to dramatically increase the number of users of telecommunication services by increasing and diversifying the services offered. One of the guiding principles is to leave the responsibility of the investments to private industry and entrepreneurs.

The biggest players in the field are the content providers, with the network providers coming second. To cable Europe requires a huge investment: for 100% coverage the costs are exorbitant; to achieve 90% coverage would require some 245 BECU, while half of this amount would allow some 75% of the population to be reached. The delivery contenders are cable and telecommunication companies, both of whom would benefit from the ubiquity, mobility and resiliency which satellites provide.

Telecommunications and industrialisation have been the route followed up to now; mass deployment of broadband access for the benefit of society as a whole is seen as the route for the next few decades. Europe is beginning to have to compete with US companies for the emerging European opportunities.

Public incentives are necessary to fill gaps and to encourage early deployment of satellite networks for covering social needs. A global strategy is required and this is, of necessity, a government/industry task. What is also required are more initiatives coming out of Europe itself for space-based services to avoid the USA getting too much of a head-start

Earth Observation

Earth observation today embraces scientific, and to a lesser degree, operational and commercial applications. While synergies can be found mostly in the operational and commercial domains, these domains are just starting to develop thanks to the availability of more numerous and more efficient data acquisition and access tools, as well as more advanced data processing and exploitation techniques. So far, the absence of a large organised operational user community has hindered the extension of operational and commercial applications.

Within the next decade, the combination of the development of new space and ground systems and of actions aimed at increasing the awareness of the user community should drastically change the picture and start to yield visible results in the earth-observation market's expansion, in terms of both hardware and applications. New high-resolution satellites and flexible operational data acquisition (with direct broadcast and transportable ground stations), coupled with new information-processing tools and networks, will bring new and more numerous products to the users, and new services and synergies will result.

Feedback from new-service demands will induce a need for continuous availability of higher spatial and spectral resolution space systems, more frequent revisits, and faster access to data. Such improvements will be made possible and affordable using technological breakthroughs in the areas of system and component miniaturisation, as well as in the area of information systems (networks, superhighways, servers, software). Such technological developments will take advantage of synergies between the civil and military domains. Automatic integration of raw, processed and value-added products into databases and geographical information systems will put the data directly at users' fingertips. New pricing policies and legal frameworks will simultaneously appear. The structures will then be mature enough for the development of market-driven initiatives on a large scale. It is widely believed that the value-added business, and in particular its GIS component, will be the largest market segment within the earth-observation field.

By 2020, maturity of operational and commercial space systems as the main sources of data in a global earth-observation system should be attained. Global Earth phenomena, as well as environmental hazards, urban development, agricultural assessments, coastal-zone evaluation and a wide range of other rapidly evolving domains, could be routinely monitored both by large and small user entities.

International institutions such as the European Union, ESA and Eumetsat in Europe, and their equivalents in the USA, Russia, China, India, Japan and many other countries with large earth-observation needs, as well as the United Nations, are expected to further develop their collaboration and to set up the large technical and political frameworks needed for a global remote-sensing revolution.

Moreover in the wake of such high-level collaboration, information highways will give a new dimension to international collaboration, putting it at the level of individual, thus expanding considerably the range of cross-fertilisation between applications and setting up a global framework of mutual assistance and education across the world, fostering links between populations and contributing to world peace.

Telecommunications

The USA is ahead in the communication satellites field. European systems are barely competitive for a number of reasons (e.g. too expensive, delays in implementation, not developed for free markets, ignoring VSAT market, etc.) and the industry does not get enough political support in marketing, which US companies do. Restrictions placed on ESA have contributed to the disappointing results in this area. ESA has not been free to select industrial partners and its role as a coordinator has never been realised. The telecommunications market requires ambitious technological developments as well as financial support, and these need to be coordinated within the framework of a reliable, long-term industrial policy and market strategy based on cooperation between the European Union, ESA and industry.

The major service trends in the communication-satellite arena include wideband, two-way, end-user communications (digital), broadcast services, personal mobile communications and navigation. The market trends include good possibilities for mobile communications and fleet traffic management, provided there is user awareness and coherency and partnerships between the various players involved. As far as technology trends are concerned, these include an explosion in new initiatives (chiefly from the USA) in regional and global systems, orbit proliferation, new frequency bands, and integrated networks. The satellites themselves will have:

- on-board switching capabilities
- multiple-beam arrays
- inter-satellite links
- more sophisticated payloads with more autonomous control.

The telecommunications industry in the USA is mature and dominated by large, vertically integrated companies. Mergers and acquisitions are required for global competition, while alliances are necessary for partners to complement each other and avoid duplication. The satellite communication industry in most countries is still fragile and is supported by Government policies and developed programmes. Global systems are challenging global regulations and it is evident that domestic policies need updating. The role and importance of developing countries is increasing and it is necessary that there is enhanced international collaboration.

New Directions and Avenues

A vision is needed of the potential roles for multilateral use of outer-space applications, and new approaches which could make them more politically and diplomatically acceptable and financially attainable need to be appraised.

A case in point is the finding of common ground between civil and military activities (e.g. in observation, monitoring, detection, communications, technologies etc.) by:
- broadening the base of interested parties (e.g. by involving the space-exploration and remote-sensing communities)
- adopting a phased-implementation approach, still keeping civil activities separated but using the same sources for data acquisition
- creation of clear and specific tasks for increasingly targeted commercial services
- identifying areas of potential partnerships or collaboration (e.g. multipurpose technologies, space-debris monitoring, dual-use of facilities, and so on).

Radical thinking is also necessary to exploit the resources that space offers in terms of energy, materials, experience, etc.

Traditional ways have to be supplemented or even replaced by new approaches in many diverse areas. New methods of financing have to be considered and public and Government perceptions have to be changed. Projects need to become goal-oriented rather than means-oriented. New kinds of customers and markets have to be found, and thus new projects need to be conceived to capture the imagination of society as well as to provide lasting benefits to all. Such topics require a certain receptiveness and flexibility on the part of both space agencies and Governments, and a high degree of willingness to change mentalities and philosophies.

One of the important questions raised is: ‘Can the space sector support more valuable and competitive services and better respond to the essential needs and operations of society?’. Typical non-space engineers’ views are that the need for the International Space Station, or more generally for manned space flight, is not obvious. There is no consensus on what spaceflight can contribute to the wealth of society in the long term. For instance, what can the space sector contribute to solve the expected dramatic shortage of water in the global village around 2020? In order to identify priorities for future European space programmes in the context of societal needs and goals, something along the lines of ‘Future Lab’ could be considered. This technique, applying socio-technical, complex and future-oriented questions, is used within some companies to provide a cornerstone for strategic planning activities. Oil companies have a similar well-developed strategic planning system, for long-term forecasting and development of scenario building as a way of trying to predict and understand the future.

Younger space professionals put particular emphasis on creating services more relevant to the public, and believe it to be the responsibility of the space agencies to develop services and technology for the benefit of mankind through international cooperation in applications such as disaster mitigation, tele-education and the understanding of global environmental and climatic issues. These ‘demands’ do not sound new to the older generation of space professionals, and the question is raised as to how public relations can be improved to close this generation gap in terms of information dissemination.

4 Trends in Research and Development

General

The major questions concerning technological trends, breakthroughs, prospects for R&D trends and policies, and space exploration as an R&D driver can be grouped under three topical questions:
- What should get priority for R&D (because it has significant long-term effects)?
- How should it be done (particularly if new approaches are needed)?
- What should ESA's role be to make technology R&D as cost-efficient as possible?

Substantial reduction of launch cost by spacecraft miniaturisation will be one major key factor for cheap access to space. Micro/nano technologies may become increasingly important in this respect in the long term. In particular, microwave equipment using MMIC technology and digital technology using ASICs and MCMs are strong candidates for cost reduction.

The system-engineering approach must be adapted to minimise life-cycle costs. Integrated design and simulation tools need to be developed for :
- rapid system-level design, trade-off and optimisation
- traffic and operations simulation, and
- high-confidence verification of baseline design.

Tele-presence should be primarily considered as a human extension in space exploration, rather than as a means for spacecraft autonomy. The latter may, however, be needed for long-duration science missions with lengthy out-of-contact periods, and autonomous navigation using GPS or pre-planned earth-observation and communication missions.

In terms of the combined effects of launch-cost and pollution, chemical propulsion seems to have reached its limits. Future scenarios should also include unconventional propulsion (e.g. laser-thermal) as a fallback option.

Hardware and knowledge-modelling software must grow at the same speed. Considerably more functions implemented in software are expected, which consequently requires a greater software integrity.

A replacement of the traditional linear process of innovation (i.e. 'techno-push') by a dynamic, interactive model characterised by the 'demand-pull' approach is needed. This may have an impact on the way ESA initiates its technology programmes. Equally well, R&D policy should concentrate on a more catalytic type of intervention, instead of large publicly funded research programmes. Publicly funded R&D should concentrate on subjects that are essential in supporting long-term applications.

Space adaptation of commercial components and validation of space components initially in terrestrial applications are essential aspects of synergy between space and terrestrial R&D. Results from terrestrial R&D must consequently be utilised in space applications, e.g. parts developed for ground applications may be used in space if properly protected. An inadequate information flow on the benefits from space R&D is considered to be responsible for the currently dwindling public support. An improvement is needed here which reaches all parties participating in the decision process for technology R&D.

A unanimous request from industry is that ESA should shorten its traditional study phases, accelerate technology transfer and provide mission opportunities for developed technologies ('Fly it'). Furthermore, ESA should co-operate with industry and universities in developing technology for low-cost missions. In addition, ESA should, wherever possible, co-operate with other space powers to achieve affordable exploration missions and involve industry for selecting technologically sound projects. ESA should also provide a long-term R&D perspective to its industrial partners.

Major Elements to be Changed

Typical examples of long-term challenges with respect to space missions and technologies, followed by trends in government-funded R&D, initiatives by industry, and general aspects of technology change need to be addressed. In particular, the need for changes in the process of technical innovation which is taking place at present in the space sector have to be addressed. Finally, the future role of European space agencies in technology R&D is an important topic for assessment.

Information technology continues to evolve, driven by increasing miniaturisation of semiconductor devices. This trend is expected to continue until around 2010/2015 for both commercial hardware and software; by then chips will probably have reached their physical limits in terms of size reduction. In this period, component price reductions by an order of magnitude every decade can be expected and reliability will improve through shear mass production, with the biggest growth being in optical systems. Chips specifically for space use are already ten years behind the state-of-the-art technology. Nevertheless, space applications of commercial parts will reduce mission costs and make unmanned missions increasingly economical compared to manned missions. The major challenges for the space sector in this field are seen to lie in software development and configuration control of software updates. Software development, in particular modelling knowledge, is falling behind what currently seems possible, especially when compared with the capabilities of parallel supercomputing systems.

Technologies driving the development of novel aerospace vehicles have to be assessed carefully for further programmatic potential. It is assumed that the combination of the limited growth potential for the specific impulse (I_{sp}) and the polluting effects in the atmosphere will reduce the relative importance of chemical propulsion in the long term. Further optimisation of chemical propulsion, combined with mitigating strategies (i.e. drag reduction by laser-produced spikes), will be effective only in the medium term.

Other propulsion systems like laser/thermal or nuclear systems and even electromagnetic accelerators have great potential, but are rather ignored in Europe's current research programmes. Japan and the USA, on the other hand, continue to support these new technologies. α-particle accelerators which offer promising cost-effectiveness in the long term also need to be considered.

Another area in which progress may alter future space flight dramatically is remote/robotic interactive space exploration – a kind of tele-exploration using interactive robots rather than man in-situ. In the long term, the goal is to transfer the human skills of exploration to the far reaches of our Solar System without the requirement of being there physically.

Overseas Initiatives

The purpose and contents of NASA's 21st Century Space and Earth Science Missions' programme could be used as an example of what is happening elsewhere regarding technology trends. This programme is being defined jointly by NASA, industry and research institutes, in order to enable low-cost missions to be conducted in the future. The effort is being concentrated in three fields: spacecraft technology, miniature scientific instruments, and transportation.

The new NASA Millennium Programme takes note of the fact that:
- space industry is now mature and there are many competitors in many countries
- the US-launcher industry cannot compete with low-cost countries that provide 'commodity' launch vehicles and spacecraft
- advanced technology is required to provide cost-effective product differentiation for the US space industry.

The programme is funded at a level 170 M$/yr for spacecraft technology (mainly micro/nano technology), and 520 M$/yr for launchers.

In Canada due to the increasing financial pressure on space activities, the commercialisation of the developed space technologies is being encouraged. Wherever possible, off-the-shelf technologies, developed in other non-space industries, are being used for space missions. The Canadian Space Agency's technology-development contracts with industry frequently require a marketing study and a commercialisation plan as specific technology-development tasks. In this way, CSA tries to ensure that the technology and its associated infrastructure and knowhow are kept alive (without the injection of further funds), so that they will be available in Canadian industry when required for a space mission.

Japan has recently announced its new long-term vision for a space-age in the next century which hinges to a large extent on international exchange and cooperation, particularly in earth observation and space science. Other fundamental aspects include the exploration of the unknown Universe and the development of creative space technologies. Activities include the construction of a Global Earth Observation System (GEOS), development of new launch vehicles (e.g. M-V and H-II) and an unmanned winged transfer-and-return vehicle (HOPE), the JEM (Japanese Experiment Module) in-orbit laboratory module, and lunar exploration projects.

General Aspects of Technology Change

Technology, although pushed in a certain direction by research, still has to fit in with the changing needs of society. Electronics is clearly one area where advances will continue to be rapid, but in many other areas advances will only be incremental, with the emphasis being on finding ways to apply existing technologies rather than inventing new ones.

It is considered that although new technologies will doubtless become available by 2020, it could be another generation before these have a material impact on people. In any event, these technologies would not be very important ones in terms of enabling a significant change in lifestyles.

Technology development will be used to keep down costs and to provide a better quality of life for people (e.g. smaller, cleaner factories, less noise pollution, better insulation and so on).

The nature of the process of innovation, in particular the changes which can be observed in all developed economies in the world (e.g. replacement of the linear 'technology-push' model by an 'interactive demand-pull' model) is considered as important. The efficiency of the overall innovation process relies on the quality of the interactions between the different actors and on the density of networks. Public intervention and private initiatives do not appear as substitutes to governmental programme plans, but rather act as complementary actions. In simple terms, one must first find out what people (users) want, then backtrack up the innovation chain of Fundamental R&D/Applied R&D/Development/Marketing. To enable this reverse path of innovation, institutional and legal structures in the space sector have to be initiated.

Selected Industrial Initiatives

It is necessary to have more 'political engineering' in the space agencies, with elements of close co-operation with industry. Clearly, small companies cannot develop competitive technologies on their own, but need the guidance of space agencies with a long-term perspective and a financial basis to guarantee a critical size for the European home market.

Industrial developments may need some additional support in order to become suitable for space use. Potential fields of application for the massive parallel supercomputer include onboard reconstruction of SAR images in near-real-time, processing of two-dimensional optical images, data compression and dynamic management of large data fluxes in multi-satellite telecommunication systems. However, it needs to be miniaturised and space-based in order to be most effective for space services. In the near term, it is expected that a 1-gigaflop processor could be developed which could be used as the core of a multitasking, real-time, onboard computer. In the medium-term, micro- and nano-technologies may allow a further reduction in mass and increases in speed and computing power.

Software is becoming a key technology for space. It may even develop into the factor limiting what can be achieved, and there is at present no consensus on how this software bottleneck can be mastered. It is one of the areas where research is called for, but today's research in the field does not seem to be solving the real application problems. The conclusion is that software research itself must also be changed.

Changes in the organisation of space technology R&D are required. In particular, distributed instead of localised R&D activities in the European space industry (because of the 'omnipresent' information infrastructure being established at present) should be the norm. More global goals, perspectives instead of spread objectives, and integrated rather than scattered funds would be welcome. ESA's role should be as coordinator of its own and national funds towards the global objective.

European space industry finds itself in an unfavourable position vis-a-vis the world market. The main competitors have strategic advantages, e.g. the US is applying very advanced technologies developed in the context of the SDI programme, China has a home market which allows mass production, Japan's MITI is providing perspective guidelines for R&D, Russia has the greatest operational experience. These factors are affecting the future position of the European space sector.

5 The Role of ESA and International Cooperation

General

Whilst it is considered that the role of the European Space Agency in the fields of science and exploration will remain basically the same as in the past, it is evident that 'space' is entering a new phase, which is characterised by an increased market orientation. In this context, the commercialisation of space applications will continue to grow, both in absolute and in relative terms, and will include many forms of earth observation, navigation, mobile communications and other fields. As a consequence of this evolution, it is clear that the market-pull will overtake the technology-push that has characterised the past decades to a large extent.

Even in the extreme configuration of complete consolidation of all space activities in Europe, the latter's industrial size remains much smaller than that in the US. Yet a strong space industry is considered to be a strategic asset for the future which Europe must acquire/preserve at all costs. It is also expected that, during the coming decades, a certain convergence of the military and civil space activities will take place, if not in terms of the actual projects, at least in a large part of the technology requirements and the administrative infrastructures.

It can generally be concluded that the public expects space to concentrate on the problems the global society, and in particular the developing countries, are facing (such as the consequences of population growth, education, environmental awareness, ecology, disaster mitigation, etc.). In order to achieve this objective, strong communication efforts are required directed towards the decision makers, money providers and the public. The decision makers, political and financial alike, must be made aware of how space can contribute in a cost-effective way to the solution/alleviation of the main problems of society.

The communication effort for the public should emphasise the results and usefulness of space activities, rather than their contents. To gain and retain the ear of the public, the level of communication must be adapted to the level of the public's understanding, while maintaining an open approach. The role of ESA in communicating to the public cannot be overemphasised in view of the impact of public opinion on political decisions.

Role of the Agency/Agencies

A prime role of space agencies is and will remain that of planning and implementing the space-science and space-exploration programmes. It is the responsibility of all agencies to enable international cooperation and to avoid duplication. Supporting industry to achieve and maintain a competitive position is also seen to be an important role, effected mainly via support to the development of technologies required for new applications and/or for low-cost, fast-schedule implementation schemes.

With respect to the preparation of new applications, the Agency/Agencies are expected to identify new opportunities, develop the associated technologies and provide demonstration opportunities to industry.

The above measures must be complemented by the provision of training opportunities, both within Europe and on a global scale (e.g. in developing countries), as well as by the active management of links with universities and education centres so as to ensure that adequate human resources are available to fully exploit the opportunities offered by space.

The agencies will become increasingly involved in the promotion of emerging activities and applications. Already today, civil space agencies are redefining their relations to the external world. As civil and military space-related services partly share the same technologies, the synergy potential between the two will be closely looked at. Moreover, this synergy – or lack of it – between military and civil space activities will very much determine the future structure of the space sector, and not only in Europe.

As public interventions are thought to be too slow for market-driven investments, space agencies will most likely stay on the sidelines when it comes to financing space-related infrastructures for commercial services. Redefining the interfaces to the external world naturally involves the relationship between industry and the agencies. As industry has to cope more and more with competitive forces worldwide, and the safety net provided so far via public budgets will be less solid, it becomes evident that industry will strongly influence the quality of this new interface. The responsibility of the space agencies could be seen as providing financial incentives for the pre-competitive part of the development which is still remote from the markets.

The Agency clearly has a role in promoting the public benefits of space activities as well as supporting the competitiveness of European industry and the space activities of developing countries. ESA should continue to implement space-science and space-exploration activities and enable greater international cooperation in these fields. Furthermore, ESA should be able to identify opportunities in emerging markets and provide demonstration opportunities which would ultimately benefit European industry. Naturally, industry would be closely associated with the definition and approval of the technology-development programmes. Working with, or even through, the European Union, ESA should also support and contribute to the development of technologies for new applications and low-cost missions.

Industry Expectations

Industry needs continuity of space activities and thus advocates the existence of a single space organisation in Europe for the public sector. In order to achieve such continuity, a long-term political will at the highest levels is required.

For ESA to be able to support industry adequately, it is considered essential that the Agency:

- possess a quick response time as well as flexible procedures enabling it to react to crash programme requirements which may develop suddenly
- possess sufficient flexibility and manoeuvrability to be able to set up, in the context of the European Union, mixed financing formulas to support the initiation of new opportunities (in fact, the creation of a MITI-type structure is advocated)
- provide 'home and global' market analysis and associate the requisite technologies with it
- encourage and promote integrated programme financing.

Considering that one of the main elements of the support to industry will be the development of technology, industry expects to be closely associated with the definition and approval of the technology development programme, e.g. by the setting up of an advisory board in which industry is duly represented.

Agencies' Viewpoints on International Cooperation

The national agencies, including Japan and India, have stressed the importance of international cooperation, taking into account the global nature of space applications, the limited resources, and the maximisation of the utilisation of acquired experience. The cooperation for the International Space Station is seen as a test case, the success of which is a prerequisite for future cooperation.

For cooperation to be meaningful, it is essential that a number of conditions be satisfied, such as: clear mutual benefits for all partners and the existence of well-defined objectives, which for large programmes may have to be split into successive phases. Successful cooperation will only be achieved if, in addition, a coherent European approach is followed, and fair and balanced conditions are adopted.

The potential risks inherent in international cooperation are acknowledged (i.e. increased interdependency and reduced flexibility), but are seen as unavoidable secondary aspects to be lived with. Furthermore, international cooperation may create difficulties during subsequent competition for pre-competitive activities. A number of potential legal and administrative obstacles must be overcome to achieve effective cooperation. These include, inter alia, intellectual property rights, data policy, common standards and the existence of an appropriate legal framework.

Outlook for the Space Station

It is evident from the discussions that the potential role of a manned Space Station was not fully examined during the Round Table. This is linked to many factors, not least the considerable uncertainty regarding the future course that Europe will take in this domain. The lingering indecision at political level on the interest for Europe of embarking on Space Station related development and operations is also linked to a more global absence of a long-range perspective for manned spaceflight beyond current Space Station plans.

International Space Station Alpha will reach the apex of its operational life during the 2020 time frame, and plans as currently drawn up by the international partners for its operations will monopolise most manned space activities during the corresponding period. By 2020, however, conclusions will have to be drawn regarding its overall performance, and decisions will need to be taken concerning its replacement, evolution, or abandonment.

The Round Table addressed the interest of maintaining and developing a manned infrastructure for the operation of cheaper payloads in space. However, this appears to be possible only in a scenario based on drastically reduced launch costs, as potentially achievable with an SSTO system for example. No definite trend towards the development of such a system can be identified today, and therefore any forecast about a positive development of the manned space infrastructure – including Space Station exploitation and evolution – is extremely uncertain beyond the current Alpha plans. In short, as for many other space programmes, development of Alpha into some more advanced concept will be a strong function of the evolution in space transportation means, their capabilities and their cost.

The International Space Station is undoubtedly one of the largest space technology drivers. However, any practical return from Space Stations operations is still very much a matter of debate. The Station is still largely perceived as a mostly technological effort, thus strongly linked to the availability of public funding, rather than an opportunity for attracting private financing – which is possibly its main handicap.

Current thinking about future space-exploration missions, eventually evolving into a manned return to the Moon, are still too much in their infancy to represent a strong booster for the Space Station as a stepping stone in that direction. Manned exploration could, however, provide the much needed long-range perspective for man-in-space activities beyond the 2020 mark, as this will clearly lead to international cooperation.

Role of the European Union

The role of the European Union (EU) may also be viewed in the above context. The fragmentation of the European space industry is one of the major reasons for its unsatisfactorily small share of the world market. With the competitive pressure expected to prevail for some time to come, European space industry has to take up this challenge, otherwise it will lose out especially to the very dynamic Far Eastern economies. Cost reduction is possibly the most important factor in terms of competitiveness, and must be supported where appropriate. Although a certain lack of common European space policy hinders the much-needed initiatives from taking place, the EU foresees increased support to the development of competitive technologies. In this context, space policy cannot be separated from the EU policy.

ESA/service provider/industry/user cooperation has to be fostered via a consistent common all-partner policy. The baseline for such a common policy will always be the careful selection of user requirements.

In the European Union space policy, the transition towards an industrial phase has already started. Economies of scale and scope will emerge via deregulation/regulation as appropriate, and the competitive strength necessary for the European space industry to penetrate these markets has to be secured.

6 Conclusions

General

After 30 years of success, it is understandable to see signs of maturity, and stagnation at present, within the space sector. Similar cycles are very well documented for many relevant sectors of our socio-economic systems. The early era of space activities concentrated mainly on developing access to space and preparing all of the necessary enabling technologies and other relevant skills. The period was characterised by:
- a very dynamic socio-economic development after 1945
- low budget limitations
- space agencies which concentrated on the execution of projects and distribution of budgets
- a developing industrial sector.

The current stage of space activities has led to the existence of basic space technologies in all relevant areas, from access to orbit, via in-orbit capabilities to ground-related infrastructure. Today's situation may thus be summarised as:
- basic technologies do exist
- the expertise is with industry (which is now in the driver's seat)
- market forces determine the developments
- numerous actors influence the development (industry has more customers)
- public budgets stay, at best, constant.

The initial objective of the 'Space 2020 Round Table' was primarily the identification of a strategic road map for Europe with respect to the future perspectives of the space sector. This road map (a possible schematic for which is shown in Fig. 1) has been outlined for several medium-term expectations, such as the recommendation of major changes with respect to policies, organisational structures and strategic R&D. The long-term perspectives have not received sufficient attention from the Round Table, because identifying a strategy for the medium-term future was considered more pressing than the long-term scenarios themselves. Thus, further work is necessary in the exploration of longer term approaches, applications and technologies.

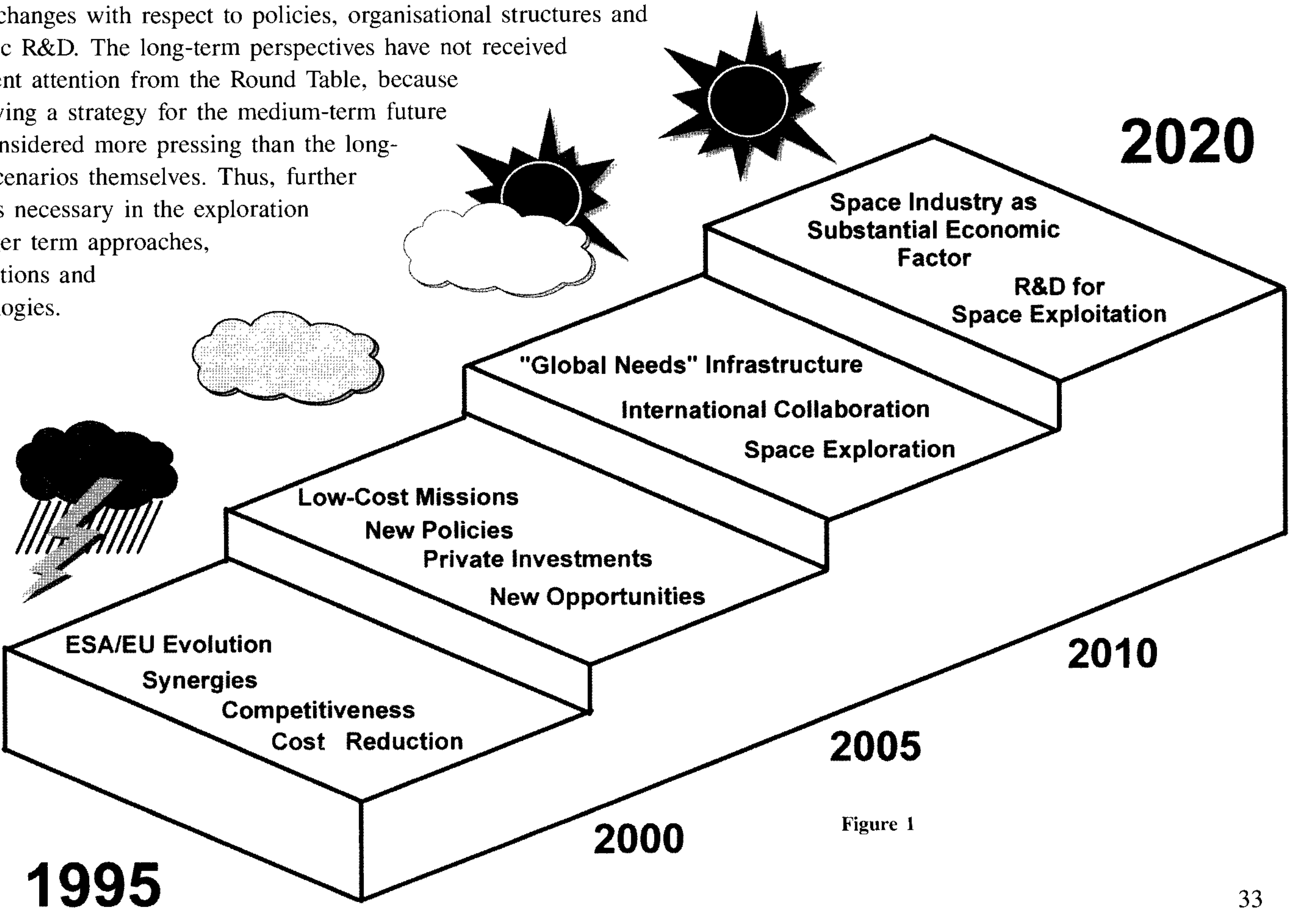

Figure 1

Today's situation in the space sector may best be described as a transition period for space towards a mature industrial and scientific sector. It is of the utmost importance to clearly assess the potential uncertainties which space will face during the years to come. Long-term thinking must prepare the strategic goals needed to guide and steer short-term management.

The space agencies have to carefully prepare a space policy according to cultural, economic, scientific and strategic objectives. Due to this pluralism of objectives, there is unlikely to be one policy which is sufficient; rather, there should be dedicated policies at least for the major areas like telecommunications, science, the environment, etc.

If one accepts a constant-budget scenario for the European civil space sector, it leads to a variety of drastic consequences:

- Private investment will be the dominant means to finance application and commercially driven space activities. New rules of the game have to be applied and space agencies could support their establishment, e.g. a consequence of this evolution is that the market (demand)-pull will overtake the technology-push which has characterised the past decades to a large extent.
- In the public context, new activities may only be added if ongoing activities are transferred, for example, to an operational entity.
- The role of the civil agencies will most likely change because of the reduction in publicly financed strategic efforts in the current space segment. Unless new initiatives (e.g. in disaster monitoring, surveillance) are able to bolster budgets, only science will remain in the picture. For space-exploration initiatives, the agencies are still the best organisations to manage transcontinental initiatives.

The Market Perspective

Optimistic forecasts for the development of future needs (commercial, scientific, technological, military) are supported by several indicators of the trends in growing markets, such as the increase in the number of telephones per capita, and the increase in expenditure for information and multimedia.

In addition, important government funds will be allocated to space-based military/defence programmes, to support national, European and United Nations peacekeeping tasks.

The new mass-market environment for satellite applications (essentially: telecommunications, navigation, observation) is characterised by:

- internationalisation and globalisation (beyond 'domestic' areas of operations)
- deregulation and liberalisation (with increases in privatisation and in competition)
- overlaps between civil and military sectors (dual-use technologies, products, potential operations)
- growth potential in developing markets (e.g. satellite TV distribution all over the world)
- digitalisation and data-compression techniques in new satellite system designs (with increased payload capabilities and efficiency)
- role of satellite constellations.

Overall, various factors are seen to occur to boost the short-term satellite market perspective. The structure of this market is characterized by:
— only a small share of the investment going into the satellite and the launcher, while
— the larger fraction is represented by operations, ground services and particularly derived services (i.e. new activities allowed by space systems applications, such as the multimedia market).

The current space business is characterized by a sort of 'vicious spiral' process. The high costs of space missions today do not allow new applications to blossom and new markets to be opened, a situation which in turn will keep space missions expensive. This 'vicious spiral' has to be reversed towards a 'virtuous spiral', leading to higher efficiency and mass markets.

The Long-Term Perspective

No matter which of the selected scenarios will prove to reflect more accurately the situation by the year 2020, it is anticipated that the major challenges for the European space sector and ESA are likely to stem from the mounting needs for commercial services in the most dynamic regions of the globe. There is a general agreement that the role of public authorities in the economy will be reduced and that a free market will be the dominant feature of the economic organisation up to 2020 and beyond.

The long-term trend seems to be a move away from large expensive space missions in favour of a greater number of cheaper missions based on using small spacecraft. Europe will require a more cost-effective strategy if it wants its space programmes to survive what is thought to be an inevitable decrease in government funding. The trend towards small and cheap space missions will also take place in Europe because of the competitive pressure from the rest of the world which is developing the required technologies for other applications.

Some of the key elements determining the future of the space sector, and of ESA in particular, are shown in Table 5.

Table 5. Key elements determining the future of the space sector

Key Elements	2000	2020
Major Players	National Authorities, International Authorities	Commercial investors, operational entities
European Trends	ESA and National Agencies still organise the European Space Sector	Organisational principle dominated by EU policy
Financing Sources	Public funding, beginning of multi-source financing	Commercial investment, venture capital
Services and Products	Technology-push is still the dominant feature in service generation	Services and products market-driven and tailored to user needs
Space Industry	Mergers and acquisitions still ongoing, also at subsystem and equipment level	One or two remaining Prime Contractor groups; subsystem and equipment companies also aggregated
Competition/Cooperation	Cooperation only in the non-competitive environment	Competition/cooperation co-exist
Synergy between Non-space Industries	Not exploited at all	Synergy will increase competitivity and efficiency

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