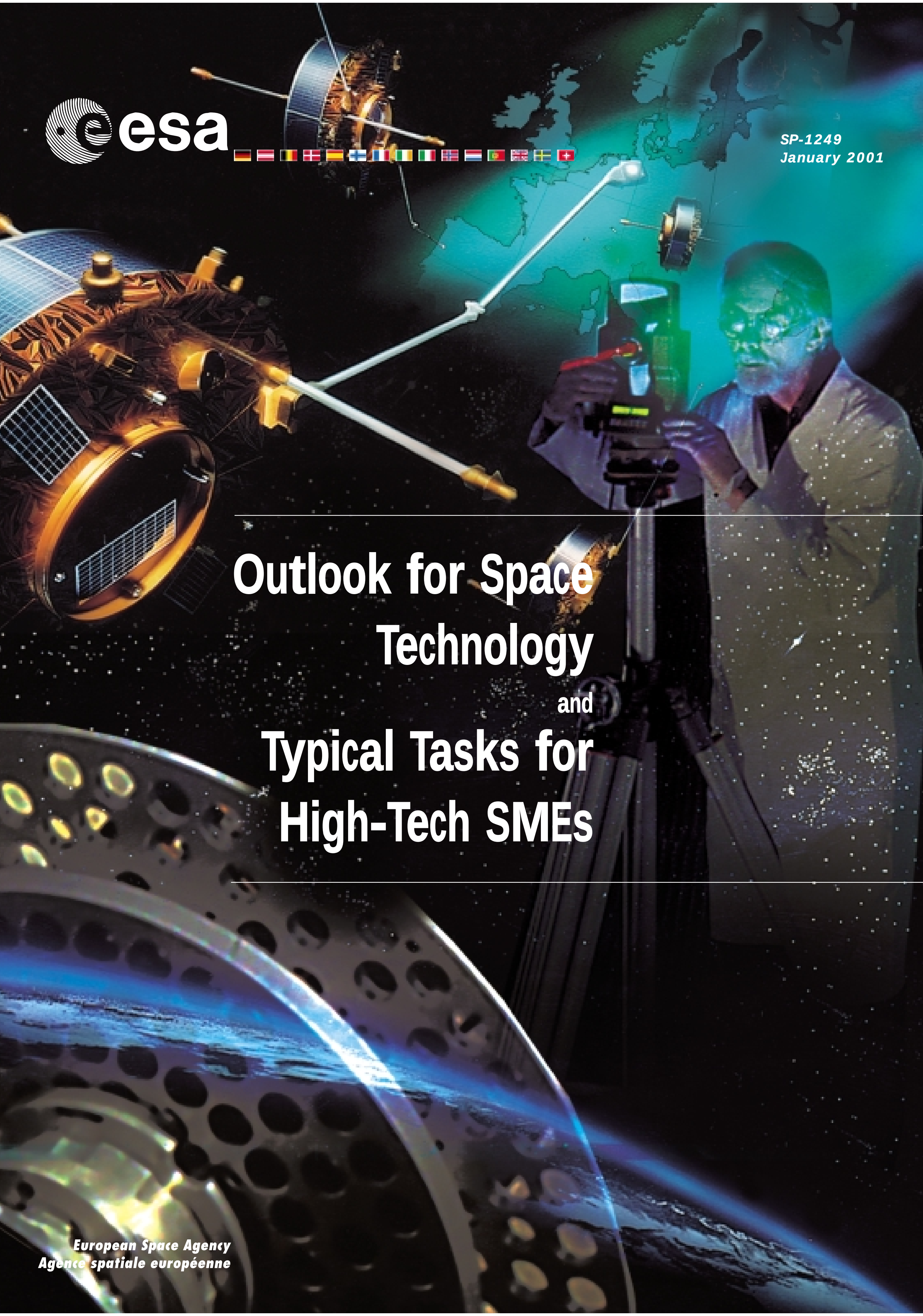

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Outlook for Space Technology and Typical Tasks for High-Tech SMEs

European Space Agency
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Contents

Introduction

The objective of this brochure is not to give a complete overview on the technologies covered by ESA or the European space programmes. The main purpose is to identify examples of relevant technology fields, in order to help small companies (especially those not familiar with these programmes) to have an idea about technologies developed for space, and about typical tasks where the contribution of high-tech SMEs could benefit both space industry and space in general.

ESA-covered activities fall into two programme categories:

- the Optional Programmes
- the Mandatory Programmes.

The Optional Programmes cover such areas as Earth Observation, Telecommunications, Navigation, Launchers, and Manned Spaceflight. With these programmes, the Member States are free to decide on their own levels of financial involvement.

Programmes carried out under the General Budget and the Science Programme budgets are mandatory. They include the Agency's basic activities, such as the Basic Technology Research Programme (TRP), the studies on future projects, activities under shared investment, information systems and training programmes. All Member States contribute to these programmes on a scale based on their Gross National Product (GNP).

This brochure focusses on the Agency R&D Programmes, which basically cover all of the technologies needed for the different space programmes, during their R&D phases. ESA has grouped its R&D activities into three main classes:

Class 1. *Prospective and Innovative R&D:* to address new enabling technologies and concepts for future space missions.

Class 2. *R&D to Support Space Projects:* to study the technical feasibility and to develop the critical technology elements of well-defined ESA and other space missions in which European industry can play a role.

Class 3. *R&D to Support Industry's Global Competitiveness:* to help European industry to consolidate and further extend its place in commercial markets, through a focussed application-oriented technology programme.

Depending on their exact nature, the maturity of the technology and the envisaged application, these three classes of R&D are covered by different dedicated ESA programmes, such as the TRP (Technology Research Programme), the GSTP (General Support Technology Programme), ARTES (Technology Programmes for Telecommunications), etc.

SMEs must be aware that hardware and software development for space requires special engineering procedures, and careful selection of technologies to cope with spaceflight conditions and constraints, which can be summarised as follows:

- harsh environment such as the thermal conditions, radiation effects, etc.
- launch conditions with high G loads resulting in vibrations
- microgravity effects modifying or annihilating physical processes based on gravity such as convection or separation techniques based on gravity (weight), etc.
- the lack of crew time combined to the cost of a space mission implies that the use of complex equipment is impossible, and that maintenance or servicing is difficult; this means that hardware reliability is a key issue
- limitations on all available resources: power, volume, up-load mass and crew time
- safety of the crew and of equipment are very important issues for manned spaceflight.

Consequently, very stringent Product / Quality Assurance (PA / QA) and safety rules are applicable for both the hardware manufacturing and any experiment procedure to be followed

CHAPTER ONE Technologies of ESA R&D Programmes

The objective of Europe's space technology R&D is to ensure effective technological preparation for future European space programmes, worldwide leadership in selected areas, and decisive support to the worldwide competitiveness of European industry. This vision, encompassing those of the individual European technology programmes, must aim at achieving high levels of effectiveness on the part of European industry. The R&D pursued must enable the implementation of the programmatic vision contained in the following strategic objectives (priorities) of the European space programmes:

- *The improvement of scientific knowledge,* through the European Space Sciences and Earth Sciences programmes, and the scientific use of space conditions on the International Space Station.
- *The improvement of quality of life,* through the European Earth Observation, Meteorological Services, and Telecommunications programmes.
- *The reinforcement of European capabilities,* through the European Earth Observation, Satellite Navigation, Manned Spaceflight, and Access to Space programmes.
- *The development of a European industry of innovation and of value-added services,* through the European Earth Observation, Telecommunications, and Access to Space programmes.

It is the intention of the ESA SME Initiative to participate in this challenge by enabling high-tech SMEs to participate in building partnerships between the different layers of industry. The Industry Space Days 2001, organised by ESA's SME Unit, are a tool to foster synergies between high-tech SMEs and the space sector, to help build partnerships between the different layers of industry, and to contribute to the global efforts of space industries.

The content of the following sections (1.1 to 1.20) is derived from the ESA so-called 'Dossier 0', which compiles the top-level ESA R&D requirements. They are only a listing of the Major Technology Axes covered by ESA within its R&D programmes. More information on these programmes is to be found in Dossier 0 itself.

1.1. Earth-Observation Technologies

- Microwave Equipment and Antenna Technologies
- Electromagnetic Techniques
- Optical Technologies
- Electro-optical Technologies
- Lidar Technologies
- On-Board Payload Data Processing Technologies
- System Elements.

1.2. Telecommunications Technologies

- On-Board Equipment Technologies
- Antenna Technologies

- Electromagnetic Techniques
- System Elements
- Ground Equipment Technologies.

1.3. Navigation and Positioning Technologies

- On-Board Equipment Technologies
- Antenna Technologies
- Electromagnetic Techniques
- Atomic Clock Technologies
- System Elements.

1.4. Science and Exploration Technologies (Solar-System Exploration Future Missions)

- Automation and Robotics Technologies
- In-Situ Instrument Technologies
- Microwave Equipment Technologies
- Optical Equipment Technologies
- Aerothermodynamic Technologies.

1.5. Science and Exploration Technologies (Astrophysics Future Missions)

- Optical Equipment Technologies
- Microwave Equipment Technologies
- X- and Gamma-Ray Equipment Technologies.

1.6. Science and Exploration Technologies (Fundamental-Physics Future Missions)

- Opto-mechanical Equipment Technologies
- Laser Technologies
- Atomic-Clock Technologies.

1.7. Manned Spaceflight and Microgravity Technologies

- Automation and Robotics Technologies
- Structure and Thermal-Protection Technologies
- Life-Support Technologies.

1.8. Mechanisms Technologies

- Micro-dynamics Technologies.

1.9. Power Technologies

- Power-Generation Technologies
- Power-Storage Technologies
- Power-Conditioning Technologies.

1.10. Thermal-Control Technologies

- Active Thermal-Control Technologies
- Low-Temperature Technologies
- High-Temperature Technologies
- Passive Thermal-Control Technologies.

1.11. Propulsion Technologies

- Chemical-Propulsion Technologies
- Electrical-Propulsion Technologies
- Solar-Sailing Propulsion Technologies.

1.12. Telemetry, Tracking and Command Technologies

- On-Board Equipment Technologies
- Antenna Technologies.

1.13. Attitude and Orbit Control System Technologies

- System Technologies
- Control Software Technologies
- On-Board Equipment Technologies.

1.14. On-Board Data-Handling Technologies

- System Technologies
- Control Software Technologies
- On-Board Equipment Technologies.

1.15. Payload Data-Processing Technologies

- Microwave and High-Speed Technologies for Digital Processing.

1.16. Components and Materials Technologies

- On-Board Equipment Technologies.

1.17. Spacecraft Operations Technologies

- Autonomy and Automated Operations
- Distributed/Decentralised Operations
- Microwave and High-Speed Digital Technologies
- Mission-Analysis and Flight-Dynamics Techniques
- Short/Low-Cost Ground-Segment Development Cycle Techniques
- Space-Debris Impact, Protection and Mitigation Techniques.

1.18. Payload Data-Exploitation Technologies

- Core Infrastructure Technologies
- Data Information Processing Technologies
- Data Dissemination and Applications Services
- User Information Services and User Interfaces.

1.19. Engineering Tools, Facilities and Services Technologies

- Design-Tool Technologies
- Testing Technologies.

1.20. Space-Transportation Technologies

- Liquid-Rocket Propulsion Technologies
- Solid-Rocket Propulsion Technologies
- Propellant Modelling Techniques
- Air-Breathing and Combined Propulsion Technologies
- Solar Thermal Propulsion Technologies
- Propulsion-System Health Monitoring Technologies
- Structure Materials, and Thermal-Protection Technologies
- Aerothermo-dynamic Technologies.

CHAPTER TWO Outlook for Space Technology and Typical Tasks for SME's

As already explained in the Introduction, the intention of the present chapter is not to give a complete overview of the technologies covered by ESA Programmes. The selection of twelve technology fields presented here is chosen to give small companies, such as SMEs who are not familiar with these programmes, a better idea about technologies developed for space, and about the typical R&D tasks in which SMEs can participate in this context.

2.1 ELECTROMAGNETISM AND ANTENNAS

2.1.1 R&D activities in this field

Antennas and Antenna Systems

These activities concern the design and development of different types of antennas and related subsystems:

- Low- and medium-gain, multifeed (shaped) reflectors, active or semi-active array antennas-smart/adaptive antennas.
- Antenna analysis and synthesis software.
- Antenna and radiating payload test techniques (compact and near-field ranges, time domain…).
- Technologies for space communications: radar and radiometry, user terminals as well as telemetry and telecommanding.

Electro-Magnetic Compatibility (EMC)

This field comprises spacecraft EM environment, charging and discharging, RF-interference, high electrical power handling and electrical hardening against interference of space and ground systems.

Electro-Magnetic Wave Propagation Phenomena

This comprises EM wave propagation relevant for space communication and remote sensing, and electromagnetic aspects of remote sensing (wave interaction, retrieval algorithms).

Opto-electronics

This field concerns different detection instruments and technologies:

- Sub-millimetre and far-infrared instruments in the 1 mm to 20 micron wavelength range.
- System design and verification techniques.
- Detector and detector-array technologies and radiometry for the X-ray, UV, Visible, IR and Far-IR.
- Photonics, quantum electronics, non-linear optics and superconductor technologies.
- Opto-electronic attitude-measurement sensors.

2.1.2 Examples of activities feasible for SMEs

SMEs can perform various design and development tasks in areas such as: telemetry, tracking & command antennas (S, C, Ku band), high-gain data link antennas, antenna modelling design software tools, antenna measurements, propagation models, wave-interaction algorithm development, millimetre and submillimetre wave antenna technology, opto-electronics, and active antennas. The following are concrete examples of developments already achieved by small companies in this field.

Antenna technology: SOPERA shaped-beam antenna

SOPERA is the result of a fast-track activity to develop a generic shaped-beam antenna for LEO satellites. Such antennas are designed to have full Earth coverage. To ensure an equal power flux density over the whole visible Earth, the antenna can be designed to have its minimum gain on boresight (nadir) and a maximum at the edge of coverage, thus compensating for the differential path loss.

The R&D activity was performed with ESA's METOP programme in mind and resulted in the pre-development of the SOPERA antenna. The antenna has now been selected to provide the high-data-rate X-band link for the METOP spacecraft. The gain enhancement at the edge of coverage (58^0 from nadir) is +5 dBi with respect to the nadir direction. The antenna has application to any LEO-satellite system, obvious opportunities being for large constellations of multi-media satellites operating in the Ku and Ka band.

Propagation / Radiometry: Atmospheric water radiometer development

Small companies participated to the development of a high-precision atmospheric water radiometer, which measures the atmospheric noise temperature at 7 different frequencies (in the 22.235 to 54.385 GHz range). The instrument system includes a highly stable temperature control system. Apart from retrieving water vapour and liquid water, it can also retrieve a temperature profile using four oxygen absorption lines.

Opto-electronics: SETIS star-sensor development

The SETIS sensor is a CCD-based autonomous optical attitude-measurement sensor, capable of locating and tracking stars with high precision, as well as small extended targets such as asteroids or distant planets. Having detected a star pattern in its field of view, SETIS then compares it to co-ordinate information contained in its internal star-catalogue memory and, after identifying a pattern match, computes its own pointing direction in inertial co-ordinates. It is thus capable of reconstituting its own orientation (and hence the attitude of the spacecraft) from an initially unknown situation – the so-called 'lost-in-space' scenario.

2.2 DIGITAL SIGNAL PROCESSING FOR ON-BOARD DATA HANDLING

Under this heading, the following sub-fields are addressed:

- Payload data-handling architectures and interfaces.
- DSP technologies, processors and ASICs.
- DSP algorithms, data reduction and compression.
- Software development for real-time DSP applications.

2.2.1 R&D activities in this field

Remote-sensing instruments and scientific payloads are generating a constantly increasing amount of data. Despite continuing progress, available transmission data rates from the space segment to the ground segment cannot meet the high telemetry requirements and on-board data reduction and storage becomes mandatory. This can be achieved by digital signal processing techniques implemented in high-performance on-board systems. Significant effort has been put by the Agency and Prime industrial companies into the development of building blocks (processor modules, high-speed links and storage elements), with the objective of simplifying the design of processing nodes and interfaces. Flexibility, programmability and scalability have been stressed and although the main elements are now available, additional developments need be undertaken to achieve the completeness sought.

2.2.2 Examples of activities feasible for SMEs

The following activities may be feasible for SMEs (the list is not exhaustive and synergies with other applications subject to harsh environments need to be considered):

- DSP ASICs development, validation and commercialisation.
- DSP software tools (real-time kernel, code generators) development and commercialisation.
- Advanced processing techniques mapping on existing processor systems including simulation and optimisation techniques.
- Development of boards for Electrical Ground-Support Equipment (EGSE) supporting standardised interfaces.
- Development of systems for testing and screening of commercial parts (COTS) needed to customise DPUs (memories, packaging techniques, FPGAs, peripherals).
- Software design techniques.

2.3 SOFTWARE ENGINEERING AND STANDARDISATION

2.3.1 R&D activities in this field

The Software Engineering and Standardisation Axis includes the methods, tools and standards that are necessary to develop on-board software for the space segment. On-board software runs on specific hardware (32-bit computer) in electronic equipment operating on a launcher or an orbiting spacecraft. The axis includes the software techniques used throughout the software life cycle (requirements, design, coding, testing and maintenance). It includes the related tools (CASE tools, compilers, software engineering environment). It also includes the standardisation aspects related to software engineering, up to the impact of software development certification. Specific needs have been identified as being more useful for the space industry:

- Fault-tolerant and autonomous software specification (formal methods), design (active redundancy, robustness, schedulability analysis, predictable executives, controlled automatic code generation, language safe subsets) and testing (automatic test generation).
- Distributed software architecture (predictable distribution, related techniques: brokers, language, distributed operating systems).
- ASIC software engineering (co-design, specific software life cycle).
- Architecture reuse, design patterns, frameworks.
- Interpreted languages.
- Hard real-time object oriented methods.
- Low-cost software-engineering environment.
- Application of software-engineering standards, certification aspects, possibly software process improvement.

2.3.2 Examples of activities feasible for SMEs

SMEs are perceived to be highly valuable in terms of contributing to space-industry projects when they have specific skills or experience in one of the following domains:

- Critical real-time software (new technologies from non-space applications).
- Distributed software architectures.
- ASIC software engineering.
- Fault tolerance/autonomy/intelligence software specification, design and test.
- Interpreted languages (Java, JVM, TCl/TK).
- Low-cost software-engineering environments (XML).
- Simulation technology, virtual-reality simulation.

2.4 SPACECRAFT CONTROL AND DATA SYSTEMS

2.4.1 R&D activities in this field

Identified below are the main technology fields related to spacecraft control, data and power systems. All of the items listed embrace the needs defined by industry or the Major Axes of the current ESA Technology R&D Programme covering the period 1997-1999.

Spacecraft Control

- Attitude Measurement and Control
- High-Accuracy Pointing

- Single Chip Control and Data System (CDS)
- Attitude Sensors
- Solid-State Gyros
- Active Pixel Sensor (APS) based Star Sensors
- Algorithms and Software
- Guidance and Navigation
- Relative Position Control of Satellite Constellations
- Surface Landing Control
- Space-Vehicle Rendezvous and Docking Control
- Autonomy
- Autonomous Command and Control Spacecraft (i.e. PROBA)
- Related Control and Data System (CDS) hardware and software technologies.

Spacecraft Data Handling

- Microelectronics
- High-Performance, Low-Power ASICs (100 000+ individual gates)
- Commercial Off the Shelf (COTS) Items with Radiation-Hardened Design
- Support ASICs for Sensor Applications
- Computing and Data Storage
- High-Performance Failure-Tolerant (FT) spacecraft computers (from 31 750 instructions per second to 100 million instructions per second SPARC)
- 10 gigabit Solid-State Recorder
- Single Chip, Integrated Control and Data System (CDS).

2.4.2 Examples of activities feasible for SMEs

Identified below is a selection of technical tasks related to spacecraft control and data systems, where it is considered that high-tech Small and Medium-sized Enterprises (SMEs) could contribute. These tasks can be classified as defining new technologies for space or exploiting new application areas.

Spacecraft Control

- Miniaturised Sensors
- Control Algorithms (Sensor Fusion, Fuzzy Control).

Spacecraft Data Handling

- ASIC Design, High-Speed Low-Power Electronics, Especially Intellectual Property (IP) Cores
- Specialised Real-Time Software for Small Embedded Systems.

2.5 SPACECRAFT ELECTRICAL POWER SYSTEMS

2.5.1 R&D activities in this field

Identified below are the main technology fields related to spacecraft power systems. All of the items listed embrace the needs defined by industry or the Major Axes of the current ESA Technology R&D Programme covering the period 2000-2003.

Spacecraft Electrical Power Generation

- Multiple-Junction Solar Cells
- Thin-Film Solar Cells
- Solar-Cell and Solar-Array Assembly Technology
- Solar-Array Solar Concentrator Studies
- Next-Generation Germanium Substrates.

Spacecraft Electrical Energy Storage

- Low-Temperature Lithium-Ion Rechargeable Cells and Batteries
- Polymer Electrolyte Lithium Battery
- Nickel-Hydrogen-Cell Improved Separator Development
- Fuel Cells and Related Technologies.

Spacecraft Power Systems and Conditioning

- High-Power (>20 kW) and High-Voltage (>100 V DC) Electrical Power Systems
- Modular Avionics for Telecommunications Satellites
- Electric-Propulsion Power Processing Unit (PPU)
- Field-Effect Electric Propulsion (FEEP) Power Control Unit (PCU)
- Electronic Power Conditioner (EPC) for Solid-State Power Amplifier (SSPA)
- EPC for High-Voltage Travelling-Wave-Tube Amplifier (TWTA) for Telecoms/Radar
- Low-Cost/Low-Voltage DC/DC User Converter Modules
- Control Driving Electronics for Cryo-coolers.

2.5.2 Examples of activities feasible for SMEs

Identified below is a selection of technical tasks related to spacecraft power systems, where it is considered that high-tech Small and Medium-sized Enterprises (SMEs) could contribute. These tasks can be classified as defining new technologies for space or exploiting new application areas:

- High-Temperature Power Electronics (for regulator mass efficiency improvement and inner planet exploration)
- Evaluation of Lithium-Ion Battery-Charge Management, Integrated Circuits (e.g. similar to those used in commercial un-interruptible power supplies)
- ASIC-based Solid-State Power Controller (SSPC)
- DC/DC Converter Modules.

2.6 PERFORMANCE-ANALYSIS TECHNIQUES FOR SATELLITE COMMUNICATIONS

Under this heading, the following sub-fields are addressed:

- Semi-Analytical Techniques
- Simulation Techniques
- Validation Tools.

2.6.1 R&D activities in this field

A variety of innovative communication-satellite systems for mobile, fixed and broadcast services, often based on complex constellations, have been announced in the last ten years and are starting to be deployed (e.g. IRIDIUM).

The magnitude of the problems implied by this approach is enormous and several aspects (from orbital mechanics, to telecommunications, operations and service guarantees during system lifetime) need to be tackled concurrently. Despite some progress in commercial products, available off-the-shelf tools are often insufficient to come up with proper integrated models of the entire communication scenario across both the space segment and the ground segment. This can be achieved by complementing existing tools (commercial and proprietary) using specific 'ad hoc' techniques implemented on high-performance hardware/software platforms.

A significant effort has been invested by ESA and Prime Contractor industrial companies in the development/customisation of building blocks for end-to-end satellite-communication-system simulation facilities, with the objective of supporting the design, validating the performance and preparing tests. Flexibility, programmability and scalability have been stressed and although some elements are now available, additional developments need to be undertaken to achieve the completeness sought.

2.6.2 Examples of activities feasible for SMEs

The following activities are felt to be well-suited for SME involvement, but the list is not exhaustive and synergies with other applications subject to similar environments will be considered:

- Semi-analytical Techniques for Performance Evaluation
- Simulation Packages on Specific Topics (e.g. Routing, Resource Assignment)
- Validation Tools.

2.7 MECHANICAL SYSTEMS AND ROBOTICS

2.7.1 R&D activities in this field

Mechanical systems as used in space projects encompass a wide field of technologies, including structures, mechanisms, optics, robotics and general instrumentation. Whereas structures and mechanisms usually form an integral part of virtually any spacecraft, optics, robotics and general instrumentation play a key role in achieving the desired mission goals and payload performances.

Considerable development efforts are being made in these technology domains to meet the demanding space-mission challenges in science, telecommunications, Earth-observation, manned spaceflight and launchers. Advanced structural concepts are being developed, along with the application of novel materials, evaluation tools and structural control techniques, to enable missions with special requirements to be realised (e.g. high-precision / stability structures, inflatable structures and structures exposed to extreme temperatures). The following paragraphs briefly highlight the technologies of interest in the different technological areas.

Mechanisms

Enabling mechanical technologies, including actuators, deployment systems, high-stability pointing and scanning, tribology, gradiometry, and mechanical micro / nano technologies or miniaturised mechanical device technologies are being developed for both scientific exploration and commercial services.

Optics

In the optical domain, the development focus is directed towards advanced techniques for optical system design, engineering and verification; optical component technology, including micro-optics, fibre and passive integrated optics; laser systems; optical aperture synthesis; interferometry and spectro-radiometric imaging.

Automation and Robotics

In the field of space automation and robotics, effort is concentrated on space-robot systems (comprising both arm-based systems for inspection, servicing and assembly of space system infrastructure or payloads and mobile robots for surface exploration on celestial bodies), and space laboratory automation and payload control systems for manned and unmanned missions.

Microgravity Utilisation

Finally, technologies are being developed to support physical- and life-sciences experiments in space, involving high-temperature material science, fluid physics, crystal growth, general biology, plant physiology, radiation biology, biotechnology and human physiology.

2.7.2 Examples of activities feasible for SMEs

In all of the areas mentioned above, there are a wealth of business opportunities for SMEs to participate in space projects with their specific expertise and technologies.

Typical examples include:

- Special mechanical products such as deployment devices, motors, actuators, slip rings, bearings, wheels (reaction / momentum / energy storage), pointing and alignment mechanisms.
- Advanced structural materials.
- Mechanical and Optical Miniaturised or Micro / Nano Technology Systems.
- Optical interferometry, metrology and aperture synthesis.
- Instrumentation for life-science experiments and diagnostics.
- Robot system technology.

With their specific contributions, SMEs will also play an important role in meeting the new challenges in space systems that result from a general shift in strategy from long-term, complex and expensive missions to those that are small, inexpensive and fast.

2.8 ELECTRIC PROPULSION

2.8.1 R&D activities in this field

Electric propulsion involves several spacecraft propulsion technologies used to perform spacecraft attitude and orbit control, as well as orbit transfers for commercial satellites and interplanetary probes. Compared to conventional chemical propulsion systems, electric propulsion requires a much lower propellant mass to perform similar operations. This implies a dramatic reduction in launch cost, as well as the possibility to increase the commercial or scientific payload on the satellite and therefore to increase its pay back. Electric-propulsion technologies include such concepts such as ion engines, plasma thrusters, arcjets, etc.

The availability on all types of new spacecraft of substantially increased levels of electrical power, used by the electric thrusters to increase the propellant consumption efficiency, now allows more widespread use of electric-propulsion systems. These systems are used mainly on geostationary telecommunication satellites, constellations of commercial spacecraft in low Earth orbits and scientific satellites of various types.

The increasing adoption of electric propulsion is generating business opportunities for companies that are able to provide products and services in this field. Following the example of American companies, these business opportunities could also materialise for European SMEs.

2.8.2 Examples of activities feasible for SMEs

Some of the fields of opportunity for the involvement of SMEs in the electric-propulsion business are as follows:

- Electric-Propulsion System Components
- Propellant-feeding system elements (valves, gauges, pipes, tanks)
- Electrodes
- Ground Services: acceptance and qualification testing of complete EP systems, and propellant filling equipment and services.

2.9 TELEMETRY, TRACKING AND COMMAND GROUND SEGMENTS

Under this heading the following sub-fields are addressed:

- Space Mission Control and Operation
- TT&C Ground Stations
- Data Communications.

2.9.1 R&D activities in this field

Due to the increased demands placed on the TT&C ground segment in terms of performance requirements (criticality of link budget, especially in deep-space missions, adaptation to extended frequency bands, use of high-data-rate transfers) and to the necessity to minimise mission costs, additional developments are required for the ground stations (antennas, receive and transmit chains, data processing, monitoring and control), for the control centres (operation automation) and for data communications.

2.9.2 Examples of activities feasible for SMEs

SMEs can be involved in R&D related to the ground stations, mission-control centres and data communications in various areas, including:

- Low-noise reception (development of cryogenically cooled, low-noise amplifiers for the S, X and Ka bands has already been contracted to an SME).
- Assessment of RF and tracking performance of large antennas at high frequencies.
- Application of digital signal processing (DSP) in ground-station receive and transmit links.
- Application of Web technologies in ground-segment data interfaces (one SME already involved in this area).
- ESA standards on space data transfers (CCSDS, ECSS).
- Operation automation concepts.
- EMC in ground stations.
- Adaptation of commercial hardware and software for use in ground facilities.

2.10 ENGINEERING AND OPERATION OF EARTH-OBSERVATION PAYLOAD-DATA GROUND SEGMENTS

2.10.1 R&D activities in this field

The payload-data Ground Segment (GS) is a key part of any mission, since it is responsible for handling the data sensed by the payloads (instruments) for interested users. The GS is even more important in the case of Earth Observation (EO) missions, because of the large data volumes and the different user categories involved.

Over time, more and more EO missions and instruments are becoming available, progressively providing a wider range of sensed data types at increasing data rates and volumes. At the same time, different user categories (research, commercial, public and military institutions, civil protection agencies, etc.) are requesting simpler and faster access to data and related products. This raises engineering issues in areas like data acquisition, processing, archiving, cataloguing, searching, retrieval, distribution, etc. A number of research activities are constantly ongoing in order to explore the new technological opportunities, which could permit the offerings in these fields to be continuously improved at declining operational cost.

The following paragraphs provide a short overview of the technologies of interest in this domain.

User Interfaces

Advanced user interfaces, based on standard browser or dedicated clients, are being exploited, for easier selection and retrieval of relevant information, data and products, from the more and more sophisticated instruments, via an interface closer and closer to natural user behaviour. This includes advanced representation also of new instruments' data (side-looking, limb-looking, higher resolutions, multi-spectral, etc.), classification of data and images through their contained features after assisted learning, knowledge-supported search, manipulation and representation of complex data in four dimensions (space and time), access through mobile devices, etc.

Payload Acquisition Planning

Advances are being explored for coping with the increasing complexity and criticality in mission-scenario analysis and in conflict-free planning (from requests and baseline needs) of payload acquisition versus the increasing number of missions (some embarking instruments with conflicting rules) and the forthcoming constellations. Planning also has an impact on or is driven by GS rules and constraints, since it includes the scheduling of GS activities like data acquisition (identifying and avoiding interference across missions), processing (bottlenecks in processing chains) and on-line distribution (availability of fast links).

Payload Data Handling

New techniques are needed in the various areas of GS data handling, including: data acquisition (cheap, simple, automatic), processing (fast, data fusion, high-level products, new formats, data access support), archiving (high volumes, fast access, on-line archiving), cataloguing (new instrument modes, altitude handling, feature extraction and classification, interoperability), searching (four-dimensional, matching user concepts, knowledge assisted), ordering / retrieval (real time, sub-sets), distribution (compression, encryption, on-line, mobile devices), facility management (automated operations, remote control, automatic fault detection and notification, decision support systems), accounting / reporting (data warehousing, data mining, automatic report generation), quality control (automatic calibration, systematic / occasional verification, and reporting).

2.10.2 Examples of activities feasible for SMEs

SMEs have plenty of business opportunities in all of the above-mentioned GS areas, since the technologies used are common to many other 'ground' activities, permitting easy and fast spin-in and spin-out. Particularly relevant are:

- User interaction (via Internet, in 3D).
- Image-classification tools (also essential for TV companies).
- Planning and scheduling techniques (used in many processes).
- Data distribution (via satellite or terrestrial links also to mobile devices).
- Data warehousing and data mining.
- Facility management.

The various activities will also benefit from the efficient structure of the SMEs, with a reduction in the turn-around time from conception to implementation. This last point is particularly relevant today, with the rapid technological evolution being experienced.

2.11 EARTH-OBSERVATION PAYLOAD DATA APPLICATIONS AND SERVICES

2.11.1 R&D activities in this field

The key objective in any Earth Observation mission is to support the users as much as possible in terms of delivering the acquired data. This requires products (or just information) best suiting user needs, implementation of specific applications, creation of services, user training and promotion. ESA follows this aim through various projects within TRP / GSTP (supporting research for product definition and service infrastructure), the Data User Programme (DUP, supporting application and service development) and the Earth-Observation Envelope Programme (EOEP, supporting market and business development).

The DUP (see http: / / styx.esrin.esa.it:5000 / DUP) and its continuation (DUP2) are optional ESA programmes, which focus on supporting the EO industry in

Participating States in bridging the gap between the research results and the establishment of operational services, based on thematic information products derived from EO data, particularly from ESA missions. The following core activities are proposed/supported, which are complementing ESA's ARTES Telecommunications programme (artes.esa.int) in these fields:

- Disaster management information products and services.
- Environmental issues.
- Regulatory treaty support.
- Pre-operational regional or global assimilation projects.

The EOEP optional programme includes a Mission Exploitation/Market Development activity (see http://earth.esa.int/eoep-market), which is focussed on supporting EO data utilisation and in promoting European industry innovation and added-value services.

The following paragraphs provide a short overview of the technologies of interest in this domain.

Support to Research and Product Definition

New higher level information products, with formats compatible with widely available user tools, are necessary in order to cope with the users' requests for high-level information, more than for images, to be interpreted. This requires research and development in feature extraction, data fusion and image interpretation, based on advanced techniques like expert systems/artificial intelligence (learning, reasoning, knowledge discovery and management), soft computing (fuzzy logic, neural networks, probabilistic reasoning, belief networks, genetic algorithms, chaos theory), information technology (e.g. user-centred computing and interfaces, intelligent agents and WEB, semantic interoperability) and telecommunications (intelligent networks, distributed/ubiquitous computing, platform independence).

Support to Applications, Services and Markets

Large activities and resources are still required to identify, design and develop applications, which can then be converted into services that successfully penetrate the market. ESA has a set of activities in progress in this field, aimed at supporting the value-adding and service industry in the design and development of the applications, as well as at implementing the infrastructure necessary to help them in defining and providing the services. The recently started GSTP Multi-Application Support Service System (MASS) project focusses exactly on this last objective, aiming at creating an Earth Observation business-to-business environment for services.

Promotion and Training

Data penetration can occur only after potential benefits are known, together with the methods for best data use. This requires training and promotion.

Training in particular can benefit from technological advances, which permit remotely assisted or self-training through a central server. Advances in these fields are constantly followed, with implementations ongoing based on expert systems supporting users in navigation and training. Tools for four-dimensional (space plus time) representation of data are being implemented as well in support of better data visualisation in training. Extension of these techniques to the Internet world will open new possibilities for knowledge transfer.

2.11.2 Examples of activities feasible for SMEs

SMEs have expertise in many of the above-mentioned areas, which are relevant for Earth Observation, but also for other commercial applications. Therefore business opportunities exist for them in both directions: applying their knowledge to EO, and applying EO techniques to other markets. Particularly relevant areas are:

- Expert systems / artificial intelligence.
- Soft computing.
- Information technology.
- Advanced telecommunications.
- E-commerce and business-to-business.
- Automated training.

The flexible structure of SMEs will be of benefit in these areas, where extensive experience and a high innovation rate are essential. Also, many activities in this group directly support the value-adding and service industries (usually SMEs), by helping them in setting up new applications and services for the market.

2.12 END-TO-END SERVICES FOR SATELLITE COMMUNICATION AND NAVIGATION

2.12.1 R&D activities in this field

The development and promotion of system elements and technologies for new user services is of prime importance to promote existing space systems and to develop the markets for advanced systems.

There is already a large base of small- and medium-sized enterprises bringing innovation into terrestrial communication applications and services, increasingly in combination with navigation services. In contrast, satellite communication often requires more lengthy preparations, with limited guarantees on the return on investment.

In ESA's Advanced Research on Telecommunication Systems (ARTES) Programme (see www.esa.int/telecom), service developments and application demonstration programmes receive high priority and are pursued within both the ARTES-3 Multimedia, ARTES-4 Partnership and ARTES-5/ASTE long and medium-term Technology Programme elements. Telemedicine, distance education, integrated navigation receivers and emergency management systems are just four typical examples.

2.12.2 Examples of activities feasible for SMEs

All activities described below are accessible to and would benefit from the participation of new entrants, SMEs with innovative technologies and service concepts. ESA is undertaking special efforts in its ARTES Programme to encourage SMEs in the growing fields of satellite communication and navigation.

Multimedia Pilot Service Developments

In the ARTES-3 programme element, the development of multimedia pilot services was started within the so-called Line 1. A number of the early initiatives have already proved their attraction in the market place, such as Espresso, Abaris, Simple and the European Medical Network (see www.esa.int/telecom). Some others are preparing for the launch of operational services (tele-medicine, tele-learning, e-commerce and business-to-business using existing satellite communication networks in a number of different configurations). These pilot projects are an essential element in the creation of a market for satellite multimedia services in Europe and Canada.

Navigation Service Developments

Early developments of novel navigation applications and services deserve a high priority in Europe. It is through such initiatives that European industry will achieve a leadership role and will eventually realise the return on investment in the European satellite-navigation infrastructures. The European Commission, national agencies and ESA are already supporting a number of initiatives. ARTES-5 concentrates primarily on application demonstrations in support of the EGNOS and GALILEO infrastructure developments, many of which also have a strong link with communication services.

Most activities address forward-looking applications, primarily in the transport sector. Any of these applications will require longer preparations and demonstrations. The EGNOS System Test Bed will provide the ideal framework for early demonstrations of state of the art of European satellite-navigation services.

Satellite Communications and Navigation for Earth-Observation Services

Demonstrations of emergency-management applications have started in ARTES-5, with the REMSAT and EMERGSAT demonstration projects, planned to be followed up by a consolidated European and Canadian initiative on the topic. These demonstration projects make use of existing space techniques, for communications, navigation and Earth observation, and integrate them for the benefit of the civil protection agencies in their management of natural-disaster situations, such as forest fires, floods, volcanoes, earthquakes, etc.

Satellite Communication System Elements and Technologies - Opportunities for Start-up Companies

A specific activity has been introduced into the ARTES-5 Workplan for 2001 to allow SMEs to address the above fields and to offer an opportunity for innovative SMEs and small start-up companies. The activity includes a survey in the identified areas of interest of the bidder, the selection, preliminary definition and possibly proof-of-concept demonstration of one or more opportunities, and their follow-up involving contacts with target user groups, operators and suppliers. The outcome will be a first iteration of an outline for a subsequent development activity including technology analysis, verification and an implementation plan for the proposed project. The primary purpose of this initiative is to facilitate entry into the satellite communications field, and hence the chosen activity should ultimately lead to a commercial proposition.

ESA intends to hold a workshop to stimulate interest and attract small start-up companies for this new opening into the ARTES Programme, followed by the issue of the Invitation to Tender (ITT). It is planned to issue the ITT at regular intervals in 2001 and subsequent years and to place several contracts to prepare start-up companies to identify opportunities with high growth potential, leading to specific market developments in the field of satellite communications services possibly supported under other ARTES Elements.

Conclusion

The SME Unit of ESA, which is sponsoring ISD 2001, hopes that, despite the fact that this brochure does not cover all European space technologies, it will be helpful to small companies by giving them an idea about technologies developed for space, and about typical tasks where their contribution could benefit space industry in particular and space in general.

Several objectives are being pursued by the SME Unit through the organisation of ISD 2001 at European level. The most obvious ones are:

- to induce further opening of European space industry to innovative ideas and technologies developed in other high-technology fields
- to help space industries to enhance their competitiveness by making use of SME's skills and expertise
- to help SMEs to diversify, to initiate new co-operations, and to find new customers for their products and services.

We hope that these objectives - or at least some of them - will be achieved during the up-coming ISD 2001, and that your company will take advantage of them.

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