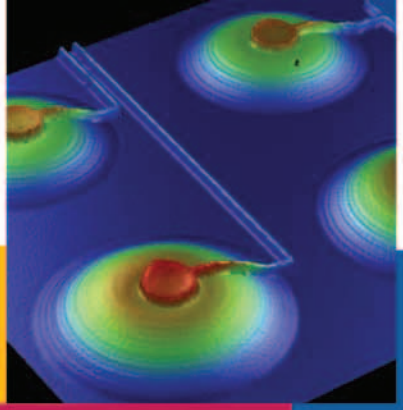
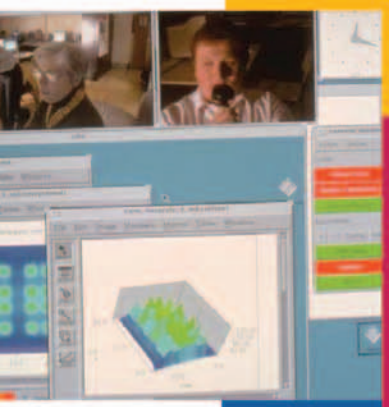




LAAS CNRS

LABORATORY FOR ANALYSIS AND ARCHITECTURE OF SYSTEMS

CENTRE NATIONAL DE RECHERCHE SCIENTIFIQUE

édito

What is **LAAS ?**

LAAS is a place committed to science, a place rich with dreams and passionate engagements towards research objects that are bringing fundamentally new ways of discovering, modeling and building the world and ourselves. It is a place for inquiring, for seeking knowledge; a place for addressing human and social queries, within a particular scientific area. It is a place for research, widely open to Europe and to the world, very active and involved into a concerned and responsible international scientific community.

LAAS is partner for producers of innovative technologies who is contributing to a rational development. It is a partner for industrial companies who is concerned with technology transfer, and with the relevance of its work with respect to social needs. It is a very active player within its rich technological environment, in particular within the *Aerospace valley*, the R&D Cluster for Aeronautics, Space and Embedded Systems, as well as within the Cluster for Medical and Biotechnologies.

LAAS is a place for scientific education, for the training of high level scientists and engineers through research and for research.

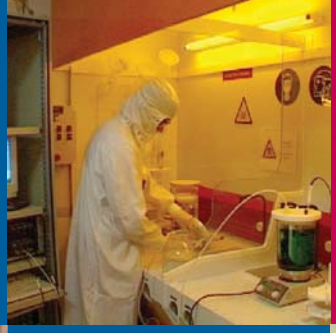
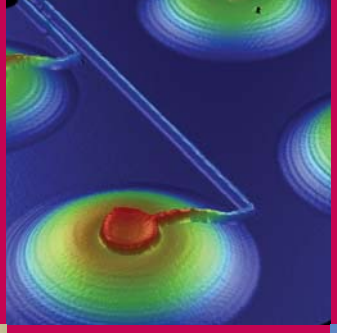
LAAS is a state of mind, the spirit of LAAS, of moral and intellectual rigor, engaged into collective actions for the general interest, enthusiastic and demanding with respect to its actions and ambitions, in order to be among the best, and to contribute to make the University of Toulouse among the best ten universities in Europe.

LAAS members are happy to offer you this brochure, which presents few aspects of our laboratory, together with the leaflet "LAAS in numbers", which illustrates our activities through few figures updated annually.

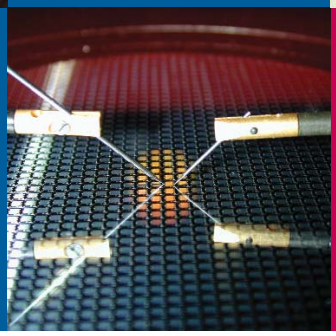
MALIK GHALLAB
LAAS-CNRS Director.

CONTENTS

OVERVIEW





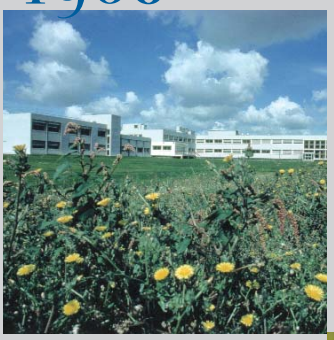

RESEARCH GROUPS

History

LAAS-CNRS has been founded in July 1967 by Professor Jean Lagasse. It is one of the laboratories of CNRS, the French National Center for Scientific Research. LAAS is closely associated to three universities in Toulouse, *Université Paul Sabatier*, *Institut National Polytechnique*, and *Institut National des Sciences Appliquées.* The members of LAAS are : research scientists at CNRS, faculty members, graduate and PhD students from these three universities, as well as engineers, technicians and administrative clerks at CNRS and the universities. LAAS originated from a scientific background in electrical engineering. It has developed a wide international status in micro-electronics, in control theory, computer science and robotics. More generally, it has played an active role in the growth of Information and Communication Science and Technology in France.

LAAS has contributed to the development of Toulouse as a well known international capital of aeronautics and space technologies. Originally, the acronym LAAS meant Laboratory for Automation and its Applications to Space. It has become now the Laboratory for Analysis and Architecture of Systems. Its research topics, fundamental or applied, are focused on the study of complex systems, within multidisciplinary approaches. Its has contributed to a variety of technological fields, from space and transport systems, to biotechnologies and health technologies, through telecommunications, software technology and energy.

1968



LAAS opening in May 1968

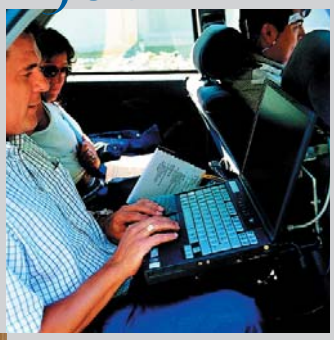
1976

Opening of the first clean room devoted to microelectronics at CNRS

1979

Hilare, first mobile robot of LAAS. Here, Hilare II

1986



Prometheus, research program on intelligent vehicle and driver assistance

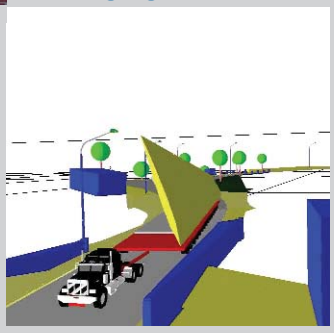
1974

Non-linear, discrete, dynamic system : chaotic behavior

1992

Creation of LIS, Laboratory for Dependability Engineering, uniting LAAS and two leading companies in their area. LAAS initiated in France joint research/industry laboratories

2001

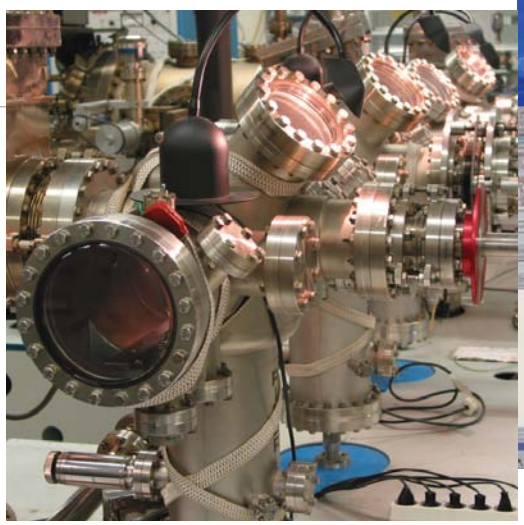


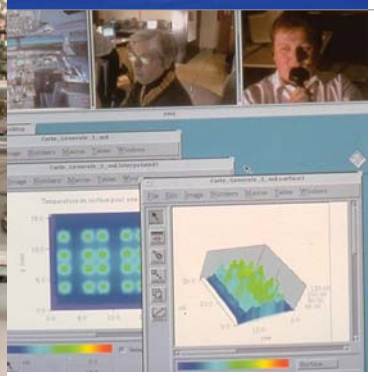
Kineo, Spin-off company of LAAS : Motion planning in Robotics for optimization of Airbus A380 components transportation

CNRS LAAS

Scientific Objectives

Information and Communication Science and Technology is a broad and fairly young research area covering Electrical Engineering and Computer Science. This area has brought new representations, original models and methods.





It has also opened novel possibilities for combining heterogeneous models and approaches in the study and design of complex systems. Indeed, scientific challenges and social demands are today concerned with highly complex systems, natural or artificial, which often require a broad and multidisciplinary approach.

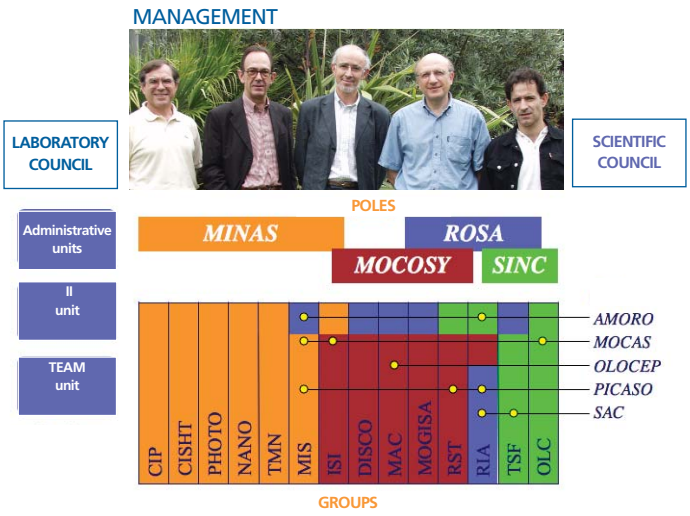
Research at LAAS strive to develop consistent approaches for understanding, modeling, designing and controlling complex systems, implementing heterogeneous mathematical representations, multiple and partial models, as well as open systems, interacting with the external world, with human operators and with other systems. These studies are concerned with theoretical models and representations, design techniques, virtual prototyping, implementing, integrating and experimenting with complex systems, taking into account predictability, performance, cost, safety and reliability issues for such systems.

LAAS is mainly interested in four classes of systems, through its four thematic research areas:

- **Micro and Nano Systems** (MINAS) area, which is concerned with microelectronic technologies, with the design and modeling of micro and nano systems for handling information and communication, for the management of electrical energy, and for chemistry and life sciences applications;
- **Modeling, Optimization and Control of Systems** (MOCOSY) area, which is particularly interested in aeronautics and space systems, biotechnologies, telecommunications, and manufacturing applications;
- **Robotics and Autonomous Systems** (ROSA) area, which studies sensori-motor functions, perception, interpretation, planning and decision making capabilities, and how to integrate these functions into cognitive architectures;
- **Critical Computer Systems** (SINC) area, which is concerned with architectures and communication protocols, with quality of service, networks and their metrology, with multimedia cooperation, with fault tolerance, safety and security of computer systems.

To address these complex systems, LAAS favors as much as possible multidisciplinary approaches, integrating scientific issues from microelectronics, computer science, control theory or signal processing. Furthermore, several research projects at LAAS involve external collaborations with other scientific fields: mathematics, physics, chemistry, life sciences, engineering, and human and social sciences. For example, the collaborations with biology and life sciences concern micro- and nano-biotechnologies (nano-addressing, biochips, micro-fluidics), bioinformatics and biomathematics (modeling and dynamics of bioprocesses, algorithmic of biochemical interaction), robotics and medical technologies.

Organization



The director, Malik Ghallab, with the deputy-director, Antonio Munoz Yague (to his left), and the three vice-directors, Michel Diaz, Raja Chatila and Germain Garcia (from left to right)

PURPOSE OF LAAS-CNRS

- **Advancing the scientific knowledge**
- **Training, for research and through research**
- **Applying scientific results to industrial and social problems**
- **Spreading the scientific knowledge and culture**

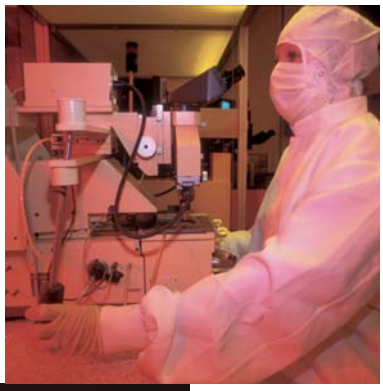
Research at LAAS takes place within research groups. The four thematic areas of the laboratory are overlapping: several groups belong to more than one area. However, thematic areas offer means for coordinating research activities, in particular through the cross-disciplinary research projects of the laboratory.

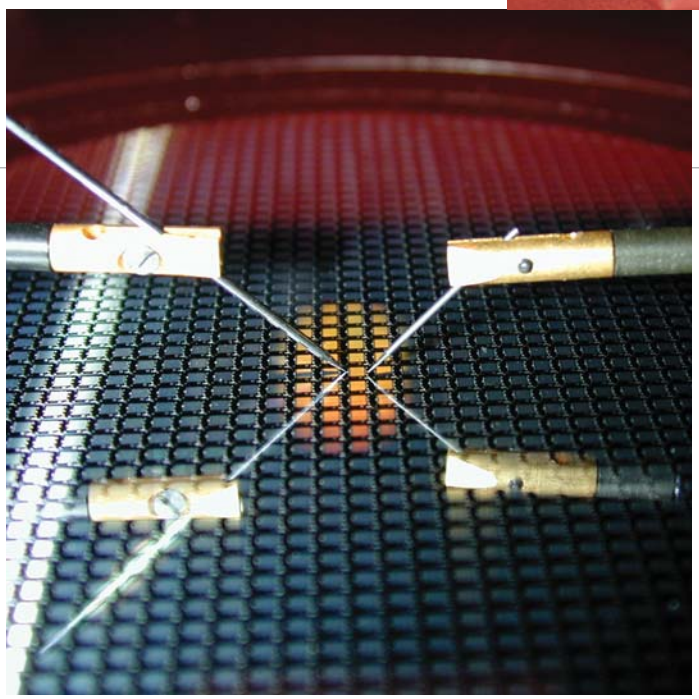
The technical staff is organized into two technical units. There are few administrative units for the management of the laboratory. A Scientific Council advises on the scientific policy and projects of the laboratory. A Laboratory Council, with one half of its members being elected, advises on the organization and the management of the laboratory.

The management of LAAS is run by a director, helped by a deputy-director and three vice-directors, who are in charge of the four research areas of the laboratory. The management team includes also the leaders of the research groups and of the technical units.

Micro and Nano Systems

The topics studied in the MINAS research area involve around 70 permanent LAAS researchers and as much PhD Students, divided into six research groups.





Fabrication and test of devices and microsystems

The works in the micro- and nano-systems field cover three main aspects:

- **Technological processes,** associated to the physico-chemical mechanisms at a micro- and nanometric scale ; elementary properties of the materials and interfaces; problems linked to integration, including feasibility, reproducibility and reliability requirements.
- **Physical processes** within structures and devices; performance limits, taking into account coupled physical mechanisms and interactions with the environment.
- **Modeling and designing devices and micro-systems** to be integrated within a system for a global function, in closed link to the technological manufacturing of test devices and prototypes for validation.

The main aim of these studies are the integration of materials, technologies and functions, the reduction of dimensions and the development of new functions; they can be split up into three main fields:

- **Micro and nano systems for information and communication.** In Si and GaAs technologies, the aim is the development and integration of micro and nanometric structures within devices, such as dielectric layers and ultra-thin junctions in MOS devices, diffractive structures and photonic crystals, hetero-structures with quantum wells or boxes for laser emission, and circuits and micro-electromecanical systems for communications.
- **Micro and nano systems for managing electrical energy.** The idea is to improve the performances and functions of electronic power components, integrating control of the switch and protection against overloads, electrostatic discharges, etc. New materials (magnetic, ferroelectric,…) and their associated technologies are also considered for developing passive elements (inductances and capacitances) needed in a 3D integration of the commutation cells.
- **Micro- and nano-systems for physics, chemistry and life sciences.** Work is focused here on sensors using microelectronic components, bio-detectors based on MEMs and nano-devices, functions of micro-fluidics and their integration, as well as nano-addressing structures. The main objectives are the development of chemical or biological sensors for analysis or process monitoring, lab-on-chip and biochips, and devices for addressing and studying nanometric-sized objects.

Modeling, Optimization and Control of Systems

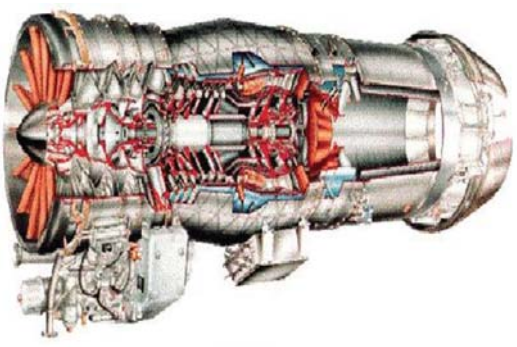
The research topics of the Modeling, Optimization and Control of Systems (MOCOSY) area include the methods and techniques allowing the modeling, the optimization and control of a wide variety of complex dynamical systems.

Among the systems of interest, we can mention biotechnological and ecological systems, aeronautics and space systems, production and activity systems. The problems to be solved are due to a complexity whose origin is diverse. For instance, a source of complexity can be due to phenomena which cannot always be perfectly modeled, to the geographic distribution or the number of heterogeneous components of the system. Control actions of such systems are also diverse and depend on the considered level. They lead to several approaches of a same system and lead to multiple techniques to integrate them within hierarchical and/or distributed control architectures. Research topics in this area are concentrated around the following main lines:

Space domain

- **Modeling:** Studies are focused on model uncertainty and the derivation of specific models for simulation, control, diagnosis and supervision.
- **Optimization:** Original works are developed in the fields of global and discrete optimization, semi-definite programming and use of constraints propagation techniques, the underlying algorithmic and numeric problems are also investigated.
- **Control:** significant results have been obtained in the case of robust control, nonlinear control, control with saturated sensors and actuators or vision-oriented control.
- **Estimation and Filtering:** particularly in the nonlinear case for which satisfactory answers to a certain number of hard problems (sonar, radar, etc) have been developed recently in the laboratory.
- **Supervision and Diagnosis:** diagnosis based models and/or data, using qualitative or hybrid models and fuzzy logic. AI approaches are also investigated.

Topics described above federate part of the research activities developed in the five following research groups: DISCO, MAC, MOGISA, RIA, RST. Research developed in a basic or applied context results in numerous implementations, mostly in software. Collaborations concern the following sectors: aeronautics and space, automobile and transport, telecommunications, defense, medical, etc. This area takes actively part in national and international research programs, in particular European ones.



Control of turbofan engine

Robots and Autonomous Systems

The research activities of the area ROSA address autonomous systems of any scale, including micro-systems, integrated or distributed systems.

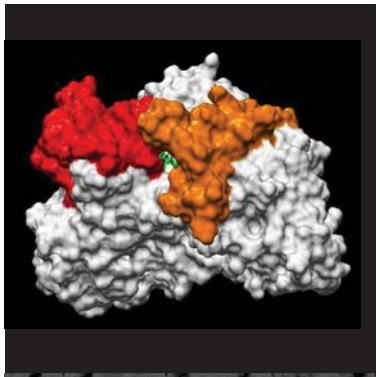
Human-robot interaction requires reliable and dependable systems

Autonomous systems exhibit perception, action and decision-making functions and interact with varying environments This raises several research topics related to:

- **Sensori-motor and cognitive functions:** multi-sensory perception and data fusion, motion planning and control, task planning and supervision, learning,
- **Critical properties of autonomous systems:** real-time architectures and embedded systems, dependability and robustness,
- **Interaction and cooperation** among several autonomous systems, or with the user.

These research problems are investigated in a multidisciplinary approach within this area which federates the competences of the DISCO, MAC, MIS, MOGISA, RIA, RST and TSF groups on these issues. Several specific projects are being pursued such as:

- Fault tolerance and dependability of robotized systems. This concerns work on robust decision-making and dependable architectures for critical autonomous systems, such as intervention or exploration robots, autonomous satellites, and robots acting in the presence of humans.
- Predictive modeling of the interactions between large bio-molecules, combining molecular mechanics/dynamics techniques and algorithmic techniques used in robotics for motion planning and geometrical reasoning.
- Design of integrated multi-spectral cameras based on micro-systems architectures such as "System On Chip", and fusion of their data with signal and image processing techniques.



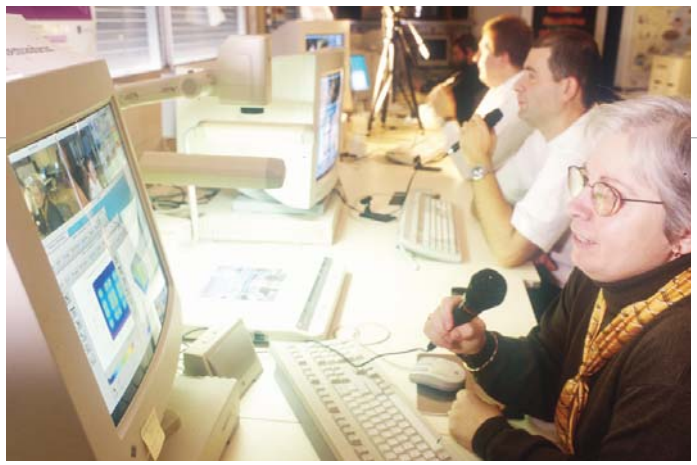
Molecular interactions modeling

Infrared and visible light views

CNRS Laboratory for Analysis and Architecture of Systems

Critical Computer Systems

Research in "Critical Computer Systems" focuses on the design of computer architectures that provide guaranteed properties for constrained advanced applications. These properties, provided by user requirements, can be defined in terms of time, security, quality of service, fault tolerance and cooperative behaviours.



Platine multimedia environment

The design of CCS must take into account all critical parameters and demonstrate that the requirements are satisfied by the provided systems. This implies developing a set of highly distributed components using a very strict methodology and adequate advanced supporting tools.
The SINC pole federates the research carried out in the OLC and TSF research groups and the one within the RST and RIA groups that deals with developing critical computerised systems.

As a consequence, research in Critical Computer Systems concerns in particular:
- system specifications and architectures,
- formal behavioural descriptions, both in terms of performance and dependability,
- validation of the model properties with respect to the defined requirements,
- implementation on target environments,
- evaluation of the implementation through stochastic models and metrology measurements.

Dependability for the New York subway

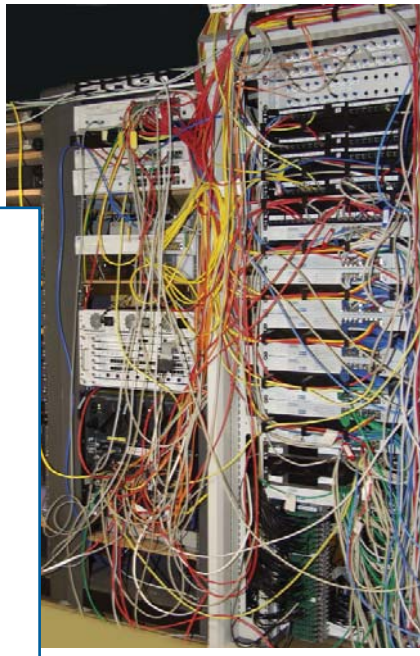
Work includes in particular studies on:
- networks and distributed systems, including their topological and compositional aspects, at the conceptual level and for their communication and cooperation architectures;
- dependability, including physical failures, software faults and intrusions, through the design of architectures and fault tolerant algorithms, of testing and analytical or experimental evaluation.

These research topics are supported by a large number of projects funded by public and industrial organisms, such as Alcatel Space, EADS, France Telecom R&D, Airbus, Astrium, Electricité de France, Rockwell Collins, Siemens, Technicatome, Realix, Silogic or Thales. In this regard, the Network for Dependability Engineering (RIS), which maintains the cooperation started within the cooperative laboratory LIS (Laboratory for Dependability Engineering), represents a good example of long-term collaboration for software–intensive critical systems. Also, CCS takes part in many national and international actions and in several projects included in French National Networks and in European Programs.

Finally, these studies include the implementation of platforms on teletraining, teleengineering, resources management, fault tolerance, authorisation schemes for the Internet, WiFi-Satellite-Wired heterogeneous networks, dependability benchmarking and metrology. These implementations are developed to support and validate the research being conducted in this area.

Informatics and Instrumentation Technical Unit

The Informatics and Instrumentation (II) Technical Unit supports the research of the laboratory in the informatics, electronics, optics, mechanics and instrumentation fields. It manages the computer resources of the laboratory, an electronics workshop and a mechanics workshop. It also deals with the management and technical support of the LAAS Microeletronic Characterization Center.



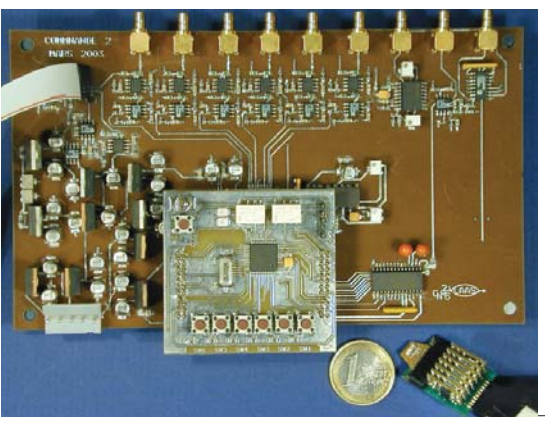
LAAS Network backbone

RESEARCH SUPPORT

The Informatics and Instrumentation unit has 20 engineers, who are involved in an average of 30 research projects. Among the projects successfully implemented by the department, or in which it has taken a significant part, we can mention:

- **the automatic module generator for the embedded software of robots, GenoM,**
- **close electronics for micro-systems of the tri-dimensional laser Tridicam, or for the piezoresistive micro-levers,**
- **the photo-voltaic units for Barcelona city and the Terrassa Science Museum,**
- **pre-distortion numeric electronic for telecommunication amplifiers,**
- **the whole mechanical part of the first prototype of the Endoxirob mechanical robot,**
- **the Platine cooperative tele-engineering platform.**

The LAAS computer resources include individual workstations (Unix workstations, PCs and Macintosh) as well as a series of servers, for all the functions which have to be managed around the Ethernet-TCP/IP network (storage, backup, data base, mail, web). The department manages all the hardware and software, supervises their functioning and plans for buying new hardware. Initial maintenance, in particular concerning the network and workstations, is dealt with internally. Training and assistance for the 500 users represents one of the main tasks of the department. Main equipment orientations and budget allotments are decided at Direction level, but each group is responsible for its own choices within the framework of a flexible development plan.



Close electronic device for Piezoresistive micro-levers

The electronic workshop is in charge of the modeling, cabling and designing of the printed circuits, and of the assistance linked to self-service work stations. The mechanical workshop is in charge of all the mechanical developments of the laboratory; recent evolution has lead to manufacture high precision parts for micro-systems and robotics.

The Charaterization Center deals with all the physical, optical and micro-electronic characterization means for the micro-systems components of the laboratory. The unit services the hardware and is in charge of the development of new measurement benches and new experiments.

The unit takes part in the big projects run by LAAS by assigning, on a yearly basis, engineers and technicians to these projects. Fifty to sixty projects are submitted each year. A Commission (Com2I), chaired by the Director, defines the support to be give to each project. The unit provides assistance, advising and technical supervision capabilities in the informatics, electronics, optics, mechanics and instrumentation fields.

Techniques and Equipments Applied to Microelectronics

The Techniques and Equipments Applied to Micro-electronics (TEAM) unit supports the research activities of the laboratory in the fields of micro-electronics, optoelectronics, sensors and micro and nano-systems, which are the principal research topics of the pole MINAS. The assignment of the engineers and technicians on projects and the appraisal of their activities are examined by a commission (ComTEAM), chaired by the Director of the lab.

Beside support activities for LAAS, this unit supports external teams at the national and European levels (IMPACT program for access to the large installations). The means are distributed in 700 m^2 clean rooms (class 10000 and 100 environments) within 12 technological zones:

ZONE OF THE FURNACES:
17 reactors allow operations of oxidation, diffusion, annealing of metals, polyimides and LPCVD or PECVD depositions.

METALLISATION ZONE: 6 deposition chambers of thin metal layers adapted to the development of contacts and specific layers.

MOLECULAR BEAM EPITAXY ZONE: 2 RIBER systems (3200 and 2300) of which one is affected with the realization of devices such as laser diodes or VCSELs and the other with devices containing fluorides.

DRY PLASMA ETCHING ZONE: 6 reactive ion etching systems specialized in the etching of type III-V materials, oxides and silicon nitrides and silicon of thin or thick layers.

MASK-MAKING ZONE: More than 400 levels masks are currently realized thanks to means of CAD tools and equipment with that pattern generator and photorepetor.

PHOTOLITHOGRAPHY ZONE: 4 mask alignment machines, single and double side, spinners and hot plates, used for implementing of the thin or thick resists.

NANOTECHNOLOGY ZONE: It contains a transmission electron microscope, adapted for electron beam lithography, an electron beam masker and an equipment of metal deposition and a machine of nano imprint.

ELECTROCHEMISTRY ZONE: It allows deposition of copper, gold, lead and iron-nickel, which are implied in the realisation of inductances and all the ultra high frequency devices on membrane.

CHEMISTRY ZONE: This zone consists on the RCA wet benches, on chemical KOH and TMAH anisotropic etching, as well as the fume hoods.

ION IMPLANTATION ZONE: It is equipped with an ion implanter of average ions EATON running and 200KV.

ASSEMBLY ZONE: Equipment of dicing, pick and place and wire bonding by ball or wedge technique, is supplemented by a flip chip equipment.

CARACTERISATION ZONE: It gathers means such as the scanning electron and atomic force microscopes, ellipsometry, mechanical and optical profilers and optical microscopes on membrane.

CHEMISTRY ZONE: This zone consists on the RCA wet benches, on chemical KOH and TMAH anisotropic etching, as well as the fume hoods.

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CARACTERISATION ZONE: It gathers facilities such as the scanning electron and atomic force microscopes, ellipsometry, mechanical and optical profilers and optical microscopes.

1- Photolithography room
2- Electrochemichal deposition benches
3- Silicon deep etching machines
4- Metals deposition systems

Administrative units

The organization and infrastructure of LAAS relies on 6 administrative units, assisted by secretaries and management assistants. These units are as follows:

Accounting Unit in charge of accounting and finances, of the budget, and of the management of grants and purchase;

Personnel Unit in charge of human resources, in particular the administrative files, the careers, the training of LAAS members, and visitors;

Partnership and Communication Unit in charge of national and international relationships, of the LAAS Affiliate partners, of communication activities and the organization of conferences;

Information Systems Unit in charge of setting up and maintaining the Web site of LAAS, as well as the databases needed by the administrative units.

Documentation and Publications Unit in charge of the publications, the scientific documentation and information retrieval, printing, publishing, video production, computer graphics;

Maintenance Unit in charge of surveying, cleaning, servicing, and maintenance of the buildings and outdoor space.

TRAINING

LAAS has a very active continuing education policy, which relies on:

- **Internal training session offered each year for laboratory members, as well as a large number of internal seminars,**
- **Education programs set up for LAAS members, including registration to CNRS training sessions, external training sessions and the organization of in situ training sessions for specific needs.**

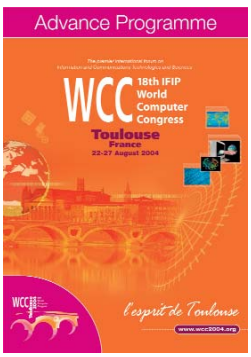
DOCUMENTATION

The library holds today 3500 books, 436 scientific journals and more than 10 000 research reports and theses. It also offers full text electronic access to more than 3000 scientific journals. The library staff offer technical assistance for search in publication databases and for bibliography. It is in charge of purchasing and lending books and articles.

The Documentation and Publication Unit manages archives and distributes LAAS publications: about 700 entries per year and 2000 distributions worldwide. It maintains the library data bases (books, magazines and publications) and manages their access through the Internet.

The publishing team is in charge of designing, editing and publishing documents, it prints around 2 million documents each year. A video facility offers equipment and help for editing scientific video documents, as well as interactive animated presentation for the Web site.

A communication policy toward partners, media and the public



COMMUNICATION

Disseminating the scientific knowledge and culture to both the professional community and the general public, is one of the four basic duties of CNRS. The LAAS has been a pioneer in this matter, by producing brochures and leaflets, by promoting its own anniversaries, and by developing and strengthening its links with official, academic and industrial partners, as well as with the media and the general public. The LAAS also publishes a newsletter, and regularly opens its doors for well-prepared visits and demos attended by a wide variety of public. This proactive dissemination policy has greatly contributed to the LAAS image and influence. The laboratory organizes in its promises or nearly about fifteen conferences every year. Its affiliates program (see insert page 21) concerns 45 industrial companies. The LAAS newsletter, published quarterly, is sent to 4000 subscribers.

Research and Education

Education for research and through research is one of the main missions of the laboratory. The laboratory offers doctorates and post-graduate training programs. About 1200 doctoral thesis have been prepared and defended at LAAS since its founding. Each year, a directory of PhD alumni of the laboratory is published. Today, about 10% of the scientific doctorates diploma delivered by Toulouse universities are prepared at LAAS.

LAAS PHD GRADUATES

Since 1968, about 1200 PhD theses, listed in LAAS alumni directory and regularly updated, have been prepared and defended at LAAS. In the seventies, 15 to 20 thesis were defended each year. Today's graduation classes represent 40 to 50 PhD students. Preparing a doctoral thesis requires about three years within a research group. The PhD programs offer a high level scientific training and allows to develop a synthetic mind, to demonstrate autonomy capabilities and to get used to positioning oneself within a very competitive international community. About half of the doctors from LAAS hold academic positions, the other half is within the industry.

The laboratory is in charge of two doctoral programs:

- The Génie Électrique, Électronique et Télécommunication (GEET) program is centered on materials, technologies and components, on microelectronics and microsystems, micro-wave and optical telecommunications, electrical engineering, plasma and discharge, radio-physics and medical imaging;
- The Systems (EdSys) program offers PhD training on control theory, dynamic systems, computer systems and industrial systems.

LAAS also offers graduate training within several programs and schools. Each year, the laboratory hosts about 250 graduate students.

LAAS is closely associated with three universities: The Université Paul Sabatier, the Institut National des Sciences Appliquées of Toulouse and the Institut National Polytechnique of Toulouse. About one half of LAAS permanent scientists are faculty members of these three universities. Some of them hold important positions: President and Vice-President of the Université Paul Sabatier, President of the scientific council of the Institut National des Sciences Appliquées, President of university departments or scientific councils, etc.
LAAS maintains active partnerships with several other engineering schools, such as SUPAERO, ENSICA and ENAC.
The laboratory Teaching and Research Commission is concerned with the problems related to the teaching activities of the laboratory members and the curricula in LAAS areas. It helps in offering and organizing sabbatical leaves.
Together with the Bernard Gregory Association at LAAS, the laboratory offers support to its PhD students for employment after graduation.

Addressing the needs of Society Partnerships, Take-up and Trans

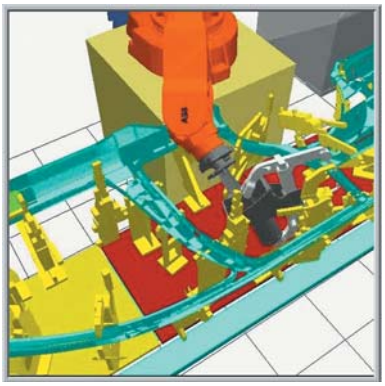
LAAS is an important socio-economic entity within its geographical and technological environment. It contributes to many industrial partnerships within joint research-industry laboratories, grants, national and European R&D collaborative projects. It undertakes R&D transfer actions, including the launch of innovative startup companies.

During the last three years, three startups have thus been launched from technological developments and research at LAAS:
- KINEO Computer Aided Motion, in the motion planning area for CAD and graphics animation;
- NEOSENS, in the area of sensors;
- QoS Design, in the area of simulation and optimization of telecommunication networks.

During the last ten years, about thirty patents have been filed in partnership with other companies; 40 technology transfer actions have been undertaken during the same period, among which 4 involve startup companies.
Joint laboratories, between LAAS and a company, offer a particularly propitious framework for partnership for far-reaching R&D projects. LAAS is partner in the following joint laboratories:
- SMARTMOS (LCIP2 and LISPA) laboratory with Freescale Semiconductors on power microelectronics;
- PEARL laboratory with Alstom on power electronics;
- AUTO-DIAG laboratory with ACTIA on automobile diagnosis;
- The RIS network, with Airbus, Astrium, Technicatome and Thales on functioning safety in critical software systems.

LAAS is also an external research laboratory for SNECMA for the control and supervision of jet engines.
Industrial partnership with LAAS also results in about sixty R&D industrial contracts per year; about thirty endowed PhDs are active at a given time. In addition to these bilateral relationships, LAAS is involved into many industrial partnerships within projects founded by national programs or European programs. An average of about two hundred and thirty projects are going on in the context of these national and international programs.

LAAS has a privileged partnership with the Association for Innovation in Industry (GIPI) and with the JESSICA association, which is in charge, on a national scale, for assisting small and medium companies in introducing or improving the electronics in their products. These two associations, which are very active in the small and medium companies of Midi-Pyrenees, are hosted by LAAS. Members of LAAS Affiliates partners are systematically invited at training sessions and other events organized by GIPI, JESSICA, or jointly with the Club.



KINEO

Kineo CAM **(www.kineocam.com) develops and markets software packages dedicated to the computation of trajectories for 3D artefacts, mechanical parts, vehicles, robots, graphical characters moving in virtual environments. Active in markets such as CAD, graphics and robotics, its product *KineoWorks* is a component which is compatible with most CAD software.**

: Socio-economic
fer

LAAS AFFILIATE PARTNERS

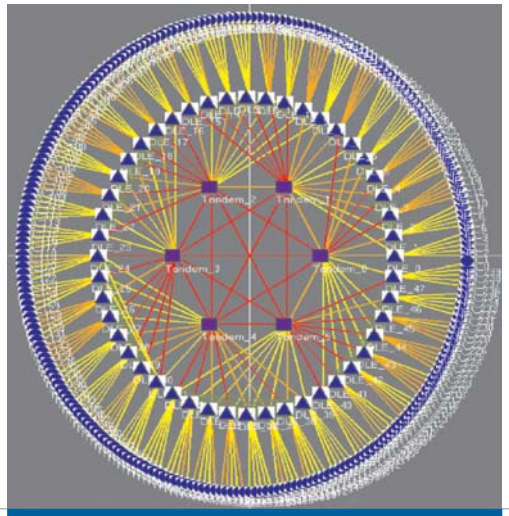
LAAS has set up in January 1990 a technical society called "LAAS Affiliates Partners".

The Affiliate Partners society hosts has about 50 member companies, mostly located in the south-west region. These companies are involved in areas and businesses directly linked with or requiring Communication and Information Sciences and Technologies, and embedded systems for Aeronautics, Space, and Transportation.

LAAS Affiliate Partners aims at creating and maintaining technological exchange and joint activities among important R&D groups, by providing them with a privileged access to the scientific results and expertise available at LAAS. The Society gives to its members the benefits and strategic services.

The affiliate partners society offers its members specific benefits :

- The organization of scientific workshops by experienced scientists; scientific and technical training session and tutorials;
- The participation to colloquiums organized by LAAS researchers, to LAAS seminars and the invitation to the defense of theses;
- Information on national and international R&D calls, assistance in setting up cooperative projects to meet these calls;
- Scientific and technological consulting;
- Scientific documentation, in particular through a permanent access to LAAS library;
- Direct access to LAAS publications, master or doctoral theses and research reports.



QoS DESIGN

QoS Design develops and markets a software called *NEST*, which is a simulation and a management assistant software for the evaluation of telecommunication networks. *NEST* is based on a hybrid simulation technology, it integrates tools for optimizing and designing secured routing policies, for dimensioning equipments and networks topology.

NÉOSENS

Néosens company, a LAAS start-up created in June 2001, has won the National Challenge prize for the creation of innovative companies. This young company commercializes dissolved oxygen sensors developed at LAAS, using a microsystem technology. Its first market is that of environment and water quality.

International Cooperation

LAAS is involved in several international actions, within international programs or through bilateral collaborations. These international activities contribute to the excellent status of the laboratory and recognition of its work.

The LIMMS is a CNRS/Tokyo University joint laboratory. It was created in 1994 and is currently headed by a LAAS scientist.

European collaborations are essential in the strategy of the laboratory. Since Esprit1, LAAS is very active in the Framework Research and Development Programs, managed by the European Commission. It has been involved in about forty projects or networks within FP5 and was the coordinator for a quarter of them. One of these project, called IMPACT, has brought LAAS a label as European platform for micro and nanotechnologies ; IMPACT has enabled to host in the laboratory a dozen European projects. The current FP6 program has twenty projects in which LAAS participates. Among them, the laboratory is coordinator of the AMICOM network of excellence, which unites 28 partners from 14 countries on studying MEMS for RF communications, and the integrated project COGNIRON, which has 10 partners from 7 countries for the development of a companion robot endowed with cognitive capabilities.

The European actions of LAAS are also funded by other European programs, such as EUREKA, the European Space Agency or NATO, or by interregional agreements, in particular those concerning the Pyrenees Work Community or those with Bavaria.

LAAS European relationships are also supported by the International Programs for Scientific Cooperation of CNRS and the Integrated Action Programs of the Department of Foreign Affairs. Good examples are the ALLIANCE program with the United Kingdom, BALATON with the Czech Republic, BRANCUSI with Rumania, PICASSO with Spain, PLATON with Greece, GALILEE with Italy, POLONIUM with Poland. Other exchanges are set up as bilateral agreements, for example the Russian-French Actions for Scientific and Technological Cooperation.

The PICS of the CNRS and the PAI of the French "Ministère des Affaires Etrangères" support the LAAS international collaborations outside Europe, in particular with Maghreb countries, Latin America, but also Australia, USA and Far East countries. The laboratory keeps close relations with Japan, in particular in the context of the Japan Society for the promotion of science and also with Hong-Kong through the PROCOPE program. LAAS researchers have close relations with American universities and research centers, among others through formel cooperation agreements such as CNRS- National Science Foundation, the France – Berkeley, or CNRS–University of Illinois at Urbana-Champaign. Several project with the Mexican universities of the Campus of Monterey are

In the framework of LAAS international partnership : Doctor honoris causa of Université Paul Sabatier and of Institut national polytechnique de Toulouse, Brian Randell, University Newcastle, Mike Brady, University Oxford, Marc Ilegens, Ecole Polytechnique de Lausanne and Pravin Varaiya, University Berkeley

INTERNATIONAL COOPERATIONS

LAAS international collaborations contribute to its standing and scientific status. Each year, several permanent members of the laboratory can benefit from different types of funding for sabbaticals in foreign countries. Its PhDs have access to funding for international stays during their thesis or as post-doctorate.

LAAS hosts each year more than twenty foreign post-docs and ten experienced scientists on sabbatical stays as CNRS associated researchers; it also welcomes many visitors for shorter periods, in the context of international cooperation. Several PhD students visit LAAS in the context of cooperation agreements with their universities, or through joint thesis co-advised by researchers of the laboratory.

Robotics campaign in Antarctica : the Nomad robot at Patriot hills

supported in the context of the Mixed French-Mexican Laboratory for Computer Science (LAFMI).

LAAS is also involved in CNRS international units. A good example is the Laboratory for Integrated MicroMechatronic Systems with the Institute of Industrial Science of the Tokyo University.

These international collaborations are implemented as visits and exchanges of researchers. LAAS hosts young researchers, post-docs and experienced researchers on sabbatical stays, in particular with the support of CNRS open positions.

Finally, let us mention the laboratory's contribution to several international societies, in particular the International Federation of Automatic Control (IFAC), the International Federation of Information Processing (IFIP), or the International Advanced Robotics Programme (IARP).

Interdisciplinary Collaboration, Partnerships

LAAS contributes significantly to the scientific resources in the Midi-Pyrenees region, one of the first in France for R&D. Its partnerships take place in particular within three research federations: Féria, for informatics and control, PUCE, for the management of electrical energy, and GREMO, for microwaves.

FÉRIA, Research Federation for Informatics and Automatic Control in Toulouse associates LAAS to two other laboratories: ONERA and IRIT. FÉRIA's actions include projects and working groups. They concern Formal Specification and Verification, Decisional Systems, Computer Security, Distributed Cooperative Simulation, Distributed Applications Programming, Embedded Systems and Man-System Interactions.

GREMO, Regional Group for Electromagnetism and Microwaves, associates LAAS to LEN7 (Electronic Laboratory of ENSEEIHT), the ADMM (Laboratory for Microwave Aerials, Devices and Materials) and SupAéro. This group implements research partnerships on micro-electronics for microwaves on silicon, and on electro-magnetic simulation.

PUCE is a federation which associates LAAS to three main laboratories, the CPAT, the LEEI and the LGET, as well as to other partners, such as the CIRIMAT, l'IMFT, the LBB, or the LGC, on problems of energy generation and storage, electrical discharges and power components and circuits.

In addition to partners involved in Féria, PUCE and GREMO, there are many laboratories with which LAAS keeps up various forms of partnership, for example:

- With LBB about the control of bio-processes
- With LCC a collaboration on chemistry and materials science
- With LGC, a collaboration program concerned with micro-fluidics
- With CESR, on micro-technologies for spatial observation
- With CEMES, on materials and structure of micro-electronics
- With National Bureau for Metrology, on sapphire resonators and SiGe transistors
- With INRA and ADEME, on valuation of solid organic residue by producing volatile fatty acids and biogases
- With LEEI, Laboratory on ultra-thin dielectric layers for micro-electronic devices

LAAS is also and involved in the Advanced Institute for Life Sciences, ITAV, which is currently set up, on the following topics: nano-biotechnology, robotics and medical technologies, bio-informatics and bio-mathematics.

Because of the broad set of topics dealt with by the laboratory, this multidisciplinary character concerns most of the scientific fields, from physics and chemistry to universe sciences, through engineering sciences. For example, studies at LAAS interacting with life sciences are concerned with micros and nano-biotechnologies (nanoaddressing, biochips, microfluidics), bio-informatics and bio-mathematics (modeling and dynamics of bio-processes, algorithmics of biochemical interactions), and robotics and medical imaging. On these problems, the laboratory has close scientific relationships with several partners, e.g., with LBB, LCC, LGC, CEMES, and with the ITAV.

National and Regional

ACI : The Concerted Incentive Actions and the other actions of the National Fund for Science support cooperative research projects, in particular in multidisciplinary fields and on emerging topics. LAAS researchers contribute to about ten of such actions.

R2IT : There are presently sixteen Technological Innovation Research Networks, in varied topics, such as food, health, materials, nanotechnologies or software technologies. LAAS takes part into 21 projects within six national networks.

PIR : The CNRS manages about twenty interdisciplinary programs distributed into several main directions. LAAS contributes to several of these programs.

LAAS national partners are quite often involved into national research groups or networks, as well as in different incentive national actions.

The laboratory has played an important part and is still very active in the following research Groups (GDR):

- GDR architecture, networks and parallelism (ARP)
- GDR algorithmics, language and programming (ALP)
- GDR information, interaction, intelligence (I3)
- GDR signal and imaging (ISIS)
- GDR automatic control and computer-integrated manufacturing (MACS)
- GDR power integration systems (ISP 3D)
- GDR Nanoelectronics (NANO)

LAAS contributes to different Concerted Incentives Actions (ACI) and to the projects funded by these actions, in particular:

- ACI Cognitive sciences
- ACI Nanosciences
- ACI Databases
- ACI Integration and Computational Neurosciences
- ACI Computer safety
- ACI Non pollution-depollution
- ACI New Processes
- ACI New analytic Methodology and Sensors

The laboratory teams are involved in many projects supported by these ACIs. They are also very present in the Research and Innovation Technologies National Networks. This is the case for the national network on software technologies (RNTL), on telecommunications (RNRT), on land transport (PREDIT), on micro- and nanotechnologies (RMNT), on health technologies (RNTS), and on the genome (GenHomme). LAAS is also present in the animation structures of some of these networks.

The national and regional partnerships of LAAS are, for a significant number of them, implemented within a multidisciplinary framework. Most of the actions supported by the ACIs are thus multidisciplinary. This feature is essential in the Multidisciplinary Programs in which LAAS takes part, in particular, in the following PIRs:

- PIR Robotics and Artificial Entities (ROBEA)
- PIR Cognitive sciences and data processing
- PIR Energy
- PIR Nanosciences – Nanotechnologies
- PIR Materials
- PIR Micro-fluidics and fluidic microsystems.

Power Integration and Devices

Electrical power consumption with 6.5 TeraKWh/year grows more quickly than for any other type of energy. The widespread use of electrical solutions, with a perspective of a sustainable development, requires a better management of electrical energy. This can be achieved by improving the intrinsic characteristics of the semiconductor devices, which control this energy, and by evolving toward integrated conversion systems. These two fields represent the core research activities of the *Power Integration and Devices* group.

Power Devices Physics and New Structures

This research activity is dedicated to the study and design of power devices, with the aim of a significant improvement of their off-state, on-state and switching performance. These studies, focused on MOS power switches, concern both lateral MOS transistors, which can be used in power integrated circuits, such as the SMART POWER ones, and discrete vertical MOS transistors. The related applications, mainly low voltage (voltage handling <150 Volts), are the automotive and the mobile phone ones.

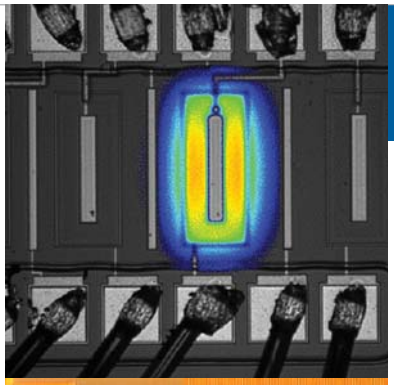
New protection structures against electrostatic discharges (ESD) are also investigated. This activity deals with the development of a new design methodology, taking into account, from the very beginning of the developing stage, the ESD robustness of the circuit. It is based on an in-depth physical understanding of phenomena, the compact modeling of the protection devices and the design of solutions providing a better ESD immunity of integrated circuits.

Those studies are supported by an extensive use of 2D or 3D physical simulation tools for the physical understanding of phenomena and device optimization as well as the use of analytical methods for the first order approximations.

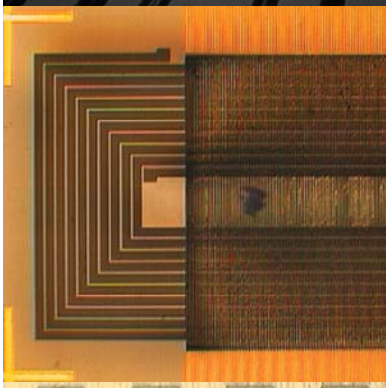
Modeling and design

The evolution of power electronics toward hybrid or monolithic integration requires to take into account, from the early stage of the design, both hardware issues and functional aspects. On the basis of device modeling, we are aiming at implementing a design methodology adapted to the specific needs of power integration.

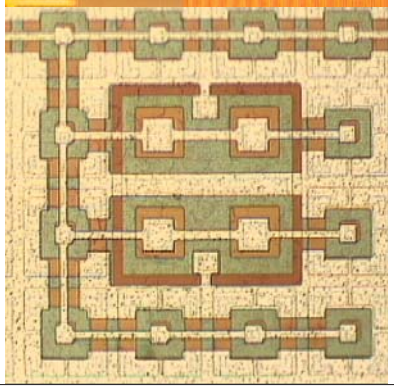
As far as electrical aspects are concerned, we develop physics-based models, allowing the description and the prediction of the behavior of devices over large range of operating conditions. The models for the main power devices have been developed and used to analyze the behavior of standard power electronic circuits and to design new integrated functions.



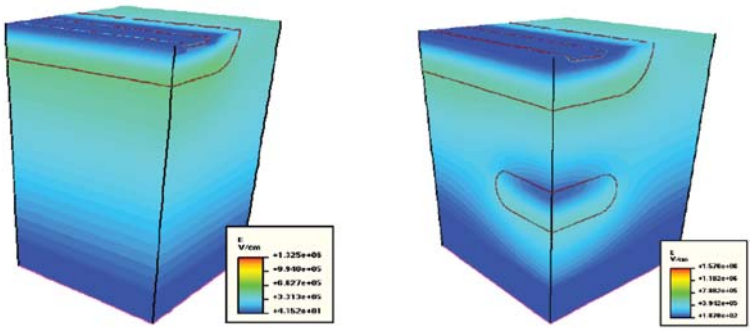
Photoemission of substrate current distribution



Integrated microcoil on silicon



Multicellular design of power integrated function



3D electrical simulation of power MOSFET

Our objectives are the modeling, the design and the silicon technology implementation of power devices and other new integrated structures. Our studies are carried out in collaboration with Freescale (previously Motorola) within the framework of the LCIP joint laboratory for power integrated circuits, with ALSTOM in the PEARL joint laboratory for transport, with ST-Tours for the functional integration devices, and in the *Power Systems Integration* national research group.

As far as thermal aspects are concerned, we deal with the 3D heat flow in multi-layer systems (substrate, supports, packages, coolers). Our approach enables both static and dynamic thermal characterization of the elements of a power assembly and the definition of their design rules. Depending on the complexity of the studied structures and the specified boundary conditions, LAASTHERM, REBECA-3D and FLOTHERM software are used for this purpose.
Special efforts are now focused on the coupling of the electrical, thermal and mechanical aspects, allowing a global design of power circuits and systems.

Power integration.

Power integration techniques aim at assembling into one or more chips all the components of an electric energy conversion system.

This integration allows:

- reducing the number of packages and connections, and as a result, their volume and cost while increasing the reliability of the system,
- adding new functions, for improved performance as far as the driving, control and protection of the power switch are concerned.

Our research work is focused on design and technology issues, related to:

- devices based on a functional integration mode, allowing the integration of driving, control and protection functions with the power element, and the development of new switching functions.
- smart power integrated circuits – and more particularly, isolation aspects between low voltage control circuits and high voltage power elements - as well as the pre-processing of low level signals, allowing an optimization of the performance of the power device (predistortion for power amplification).

According to this integration strategy, we also develop technological process flows to manufacture coils and capacitors on silicon substrates, in the perspective of providing fully integrated micro-converters for mobile electronic applications and microsystems. Investigations are focused on the optimization of specific technological steps such as deep etching, deposition of dielectric, magnetic and ferroelectric materials, aiming at an heterogeneous 3D integration of systems based on collective manufacturing. Coupling a silicon-based technology with new materials is a promising alternative option to provide new functionalities, and thus improve the electric energy conversion systems.

Microwave Integrated Devices and Systems For Telecommunications

The need for compact and efficient radio-frequency components for transmission systems, at a reasonable cost, is a requirement of the ever growing information society. Research in CISHT is focused on this field, and addresses the problems of noise, circuit integration and microsystem development.

The research of the « Microwave Integrated Devices and Circuits For Telecommunications (CISHT)" group is aimed at designing multifunction microwave integrated devices (MICs or MMICs), on silicon or compound semiconductor for passive and active devices, with innovating performances and also circuit optimal architectures. Particular emphasis is placed on design and characterization, as well as predictive modeling of electric noise and non-linear properties. We also investigate other techniques, alternative to monolithic microelectronic on silicon or gallium arsenide. For example, we work on microwave systems using an optoelectronic device in order to transport or control signal; or we apply micro-machining techniques to microwave devices. Silicon micro-machining enables us to develop high performance and very dense passive electro-mechanic microwave functions (MEMS). These MEMS are subsequently post-processed on silicon MMIC in order to benefit simultaneously from the advantages of MEMS and from those of MMIC in order to produce an enhanced microwave micro-system.

Noise in microwave devices

The reduction of electrical noise is a key element for the improvement of performances in telecommunication systems, particularly in the aeronautic and spatial industries. We deal with the problem by assessing noise, modeling active devices and designing integrated circuits. We specially focus on characterization with available facilities from 1 Hz to 110 GHz in order to analyze devices and circuits including noise from scintillation noise to millimeter wave noise up to 40 GHz. We aim at studying the elementary physical phenomena which produce electric noise, while sometimes revealing the reliability of the device; and at developing appropriate electrical models to be later used in the integrated circuits design.

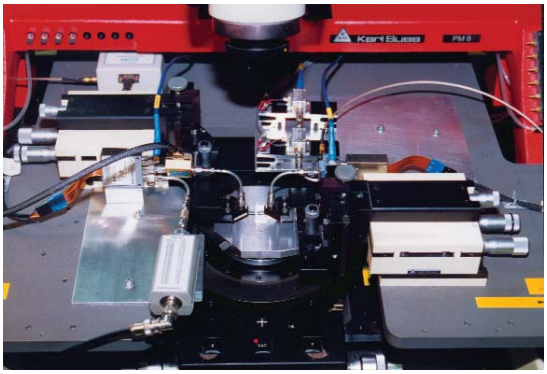
We specially adress noise modeling and assessment of non-linear devices and microwave sources. The constraints represented by very heavy bit rates in modern telecommunication systems require of these sources to be highly spectrally pure at microwave and millimeter wave frequencies. To fulfill these requirements we need to design sources from carefully selected active devices with a dedicated non-linear noise modeling. We have thus been able to implement and test different high Q dielectric resonator oscillators, the performances of which are presently the best ever achieved (around 5 GHz and 10 GHz). We also have very efficient measurement facilities up to 40 GHz for phase jitter at 1 Hz to 100 kHz from the carrier..

Finally, technologies using optical fiber in order to carry microwave signals either between two systems or within a single system open up new possibilities for more compact and lighter high performance assemblies. A modeling of their noise is however required. One of our current applications is concerned with optical distribution of frequency reference signals in a satellite.

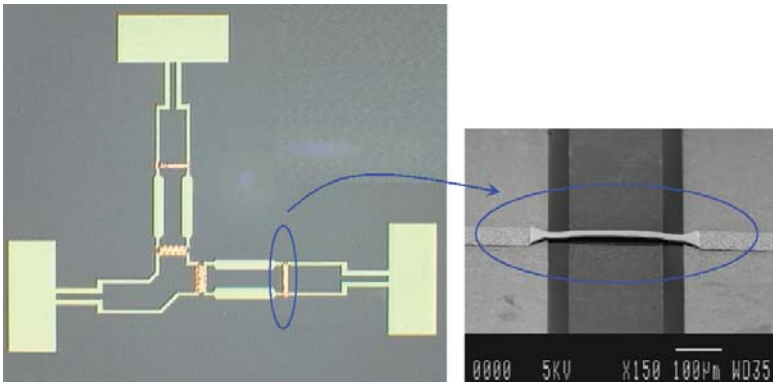
Analog and digital microwave circuits design

Cost and performance requirements lead us to integrate microwave and millimetric functions into very small volumes. The silicon-germanium and CMOS technologies are the best candidates as integration basis. We aim at designing demonstrators of high performance integrated analog and digital microwave and millimetric functions on silicon. We recently reached this goal when we produced a monolithic integration of 10 GHz, 20 GHz and 30 GHz semi-digital phase-locked loops, made from the monolithic assembly of several primary functions (frequency tripler, programmable digital frequency divider, numeric phase/frequency comparator, loop filter). Other studies concern fully digital frequency synthesis, also known as direct digital synthesis.

We also work in the field of uniplanar interconnections for designing ultra compact differential monolithic microwave circuits.. Besides, the different metal levels available today with silicon processes make possible a three-dimensional monolithic integration of some structures. All these principles have been used to design active couplers, which have been fully integrated on differential mixer high performance chips



Noise parameters measurement at microwave frequencies (up to 40 GHz)

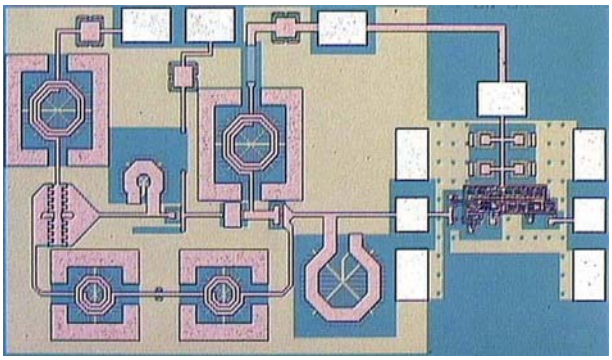


Single-pole-double-thru using MEMS switches, for redundancy circuits control in a telecommunications satellite

Microwave microsystems

For passive functions (MEMS RF), we use the silicon micro-machining processes implemented at the LAAS, associated with electrical, mechanical and electromagnetic simulation tools. Among others, we design and process micro-switches all the while retaining some kind of compatibility with traditional silicon technologies. These MEMs switches offer performances in loss and isolation impossible to achieve with classical microelectronic technologies. We presently study new structures for these devices, allowing a simultaneous optimization of both the electro- mechanic and microwave performances, including high power capabilities. We are also working on a so-called intelligent microsystem approach which consists in integrating some MEMS passive structures with active MMIC devices (low noise amplifiers, oscillators), processed with conventional techniques. We presently develop an above IC path, in which we lay an organic isolating layer on the integrated circuit and then design the microsystem on this new substrate. These studies open the way to the implementation, on a single chip, of a low cost dense reconfigurable communication system, and have several benefits with respect of the present hybrid solutions.

Besides these two research areas on microsystems design, we also study the reliability and packaging of these devices. This last study is essential for the future microwave microsystems applications, and in particular in the spatial field.



Monolithic integration on silicon of a voltage controlled oscillator and a static frequency divider at 10 GHz

Photonics

Applications in photonics involving III-V semiconductors are in a rapid and constant progress since a few years. This evolution originates from the numerous advantages that offer this technology: extended wavelength operating range, unique performances (multiple wavelength, high bit rate, …), compatible integration with microelectronic circuits and MOEMS (mechanical optical electronic microsystems).

These new demands imply extensive research efforts on the fabrication and development of materials, devices and systems, in order to strength the role of photonics in its established fields of competence (in particular communications) and/or to access new application domains. It leads to the growth of technologies for innovative devices or integration of optoelectronic components within hybrid systems. It finally needs thinking out the nature and architecture of systems with significant optoelectronic contribution.
In this context, our studies are focused on the design and processing of optoelectronic devices using prospective materials or physical effects and/or offering new functionalities.

Materials and technology

■ Epitaxy

In addition to 840nm emitting GaAs/GaAlAs quantum well structures, GaInAsN/GaAs quantum well and GaInAs(N)/GaAs quantum dot based structures are developed using molecular beam epitaxy. The goal is to extend the GaAs optoelectronic applications toward 1.3 – 1.55µm. Real-time thickness control for VCSEL multilayers can be achieved by means of the Tunable Optical Reflectometry technique with a white light source.

■ Fabrication Technology

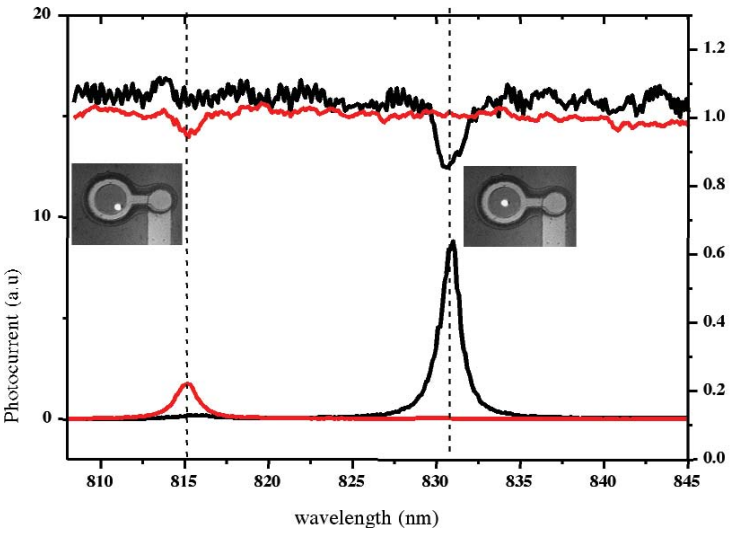
The technological process for laser diodes and vertical micro-cavity devices is mastered. In particular AlOx wet oxidation of AlAs is exploited to generate a buried dielectric aperture which leads to an efficient electrical and optical confinement. Polymer nano-imprint is used to produce submicronic patterns on the surface of fluorides and GaAs, in collaboration with the NanoAddressing group. The aim is to imprint polymer gratings in view of achieving optical functions for fluorides, to tailor the growth of semiconducting low dimensionality strained objects or to produce photonic crystals.

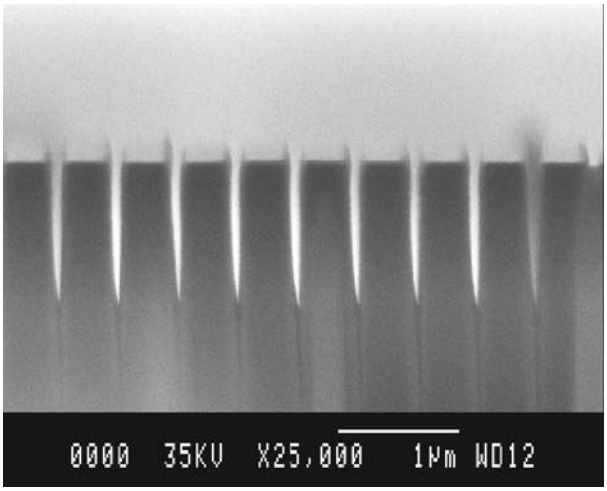
Amplifiers and 1.3µm laser

This wavelength, which corresponds to the dispersion minimum of the silica fibers brings some advantages in the device operation. Studies are focused on the design, fabrication and characterisation of three types of devices:

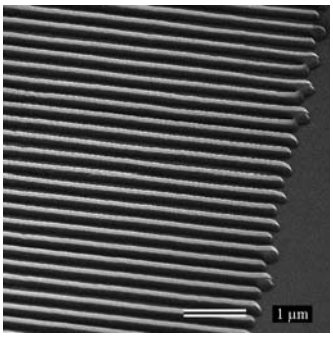
■ **Rare-earth doped fluoride active waveguides:** These waveguide cores have been doped with different rare earth elements (Nd, Pr et Er), but our present demonstrations mainly lie on neodymium doped fluoride active layers. In particular, 1.06µm microlasers have been demonstrated and 1.3µm microamplifiers are developed.

Localized photocurrent and reflectivity spectra measured in the emission (a) and oxidized zones (b) of an oxide-confined VCSEL used as a detector demonstrating oxide detection modes





(a)



(b)

Electron Microscopy observation of gratings obtained: a) by dry etching into GaAs and b) by nano-imprinting into a polymer (collaboration with the Nanoaddressing Group)

■ **GaInAsN/GaAs (100) quantum well laser diodes** for access networks emitting at 1.3µm. This new material enables an improvement of the thermal stability of actual sources.

■ **Vertical cavity surface emitting lasers** (VCSELs): studies deal with the controlled epitaxy under in situ tunable reflectometry, optimisation of Bragg reflectors and electrical injection for AlOx buried oxide devices.

Devices with new functionalities

■ **Microcavity devices:** Ability for single or double cavity VCSEL devices to act as dual alternate or simultaneous emitter/detector is addressed. Bi-VCSELs with coupled cavities are also studied for Terahertz generation.

■ **Nanolasers based on forbidden band gap photonic structures:** Photonic crystals open up the way to new semiconductor laser sources for integration within a photonic circuit. Our goal is to demonstrate the feasibility of electrical pumping and illustrate the use of photonic crystals lasers in telecommunication applications.

■ **Spin-polarized light emitting diodes**

Studies are developed on Spin-polarized light emitting diodes, obtained by associating III-V semiconductors to a ferromagnetic material, in view of investigating spin relaxation during carrier injection and transport.

Optical Microsystems

■ **Frequency Stabilized Laser Microsources**

Laser microsources, produced by silicon hybridization of a laser diode with a Bragg grating and a micro-mirror, enables a robust and miniaturized configuration of external cavity laser diodes. We use this approach to improve the quality of the laser diode emission for metrology, instrumentation or telecommunication optical applications.

■ **Microsystems for optical instrumentation**

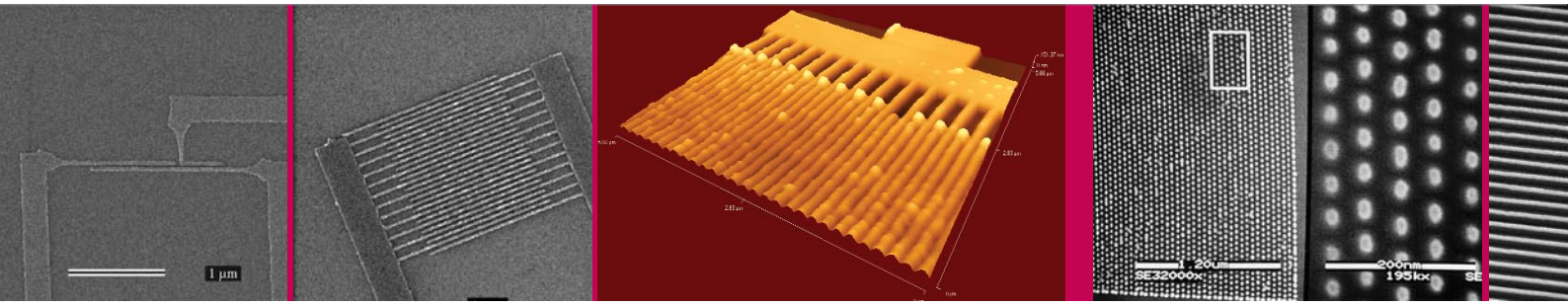
Miniature optical systems or innovative photonic systems can be developed on the basis of the MEMS and microelectronic concepts. We study the use of CMOS conventional technology to realize integrated functions within optical sensors, such as "smart detection" or " interference detection".

■ **VCSELs and microsystems**

The use of VCSELs in an optical detection microsystem, part of a microsensor for biological analysis, as well as in a probe optical microsystem for near-field microscopy is under study. These two applications take benefit from the quality of the emitted beam and from theparallelism naturally accessible with the VCSELs sources.

Nanoaddressing, Nanobiotechnologies

How can we inject a signal or collect an output from a small system of only a few nanometers in size ? One of the main objective of the group is to develop and validate new concepts for achieving smart addressing at the nanoscale. The purpose is to discover new process for achieving intelligent interconnections between "Bottom-up" systems like molecules, self-assembled particles and Microelectronic devices and Microsystems. Electrical, mechanical and optical addressing nanosystems are under investigation. Nano-addressing concepts are applied to biosystems. The group develops nanofabrication techniques for biopatterning and innovative nanosystems for detecting specific hybridations between biomolecules using electrical, mechanical and optical means.



(a) ***Various patterns of nanoelectrodes generated by electron beam lithography for electrical nano-addressing, ultimate dimensions are below 10 nm. Left image, the gap between nanoelectrodes is 20 nm. Middle image, the gap is 30 nm, the total length of the interdigitated electrodes is larger than 75 µm with no short-cuts. On the right, AFM image of interdigitated nanoelectrodes.***

(c) ***Left side : Utra high density mold fabricated by Electron beam lithography (period 40 nm, 400 Gbit /in2), middle : Nanostructures***

One of the main objective of the "Nano group " in LAAS is to develop and validate new concepts for achieving smart planar addressing at the nanoscale. This scientific activity is declined among three axes corresponding to the various modes of interaction with the nanosystem : Electrical addressing, Mechanical addressing and Optical addressing.

Electrical nanoaddressing

We develop new techniques and processes for contacting electrically nanometric objects like nanotubes, nanoclusters, DNA molecules, proteins. Two main objectives are pursued : i) fabricate extremely narrow nanoelectrodes, ii) locate the nano-object of interest precisely in-between these nanoelectrodes without any denaturation. The Nano-objects under study are elaborated by different academic nearby partners.

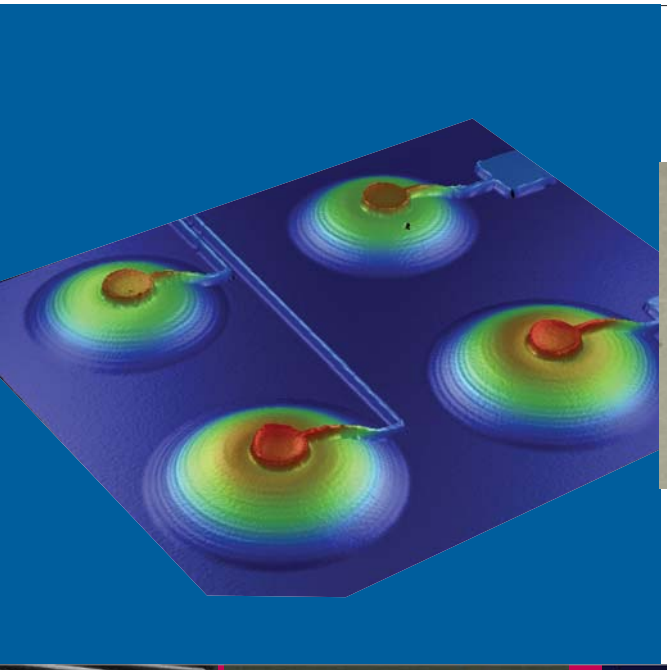
Mechanical Nano-Addressing

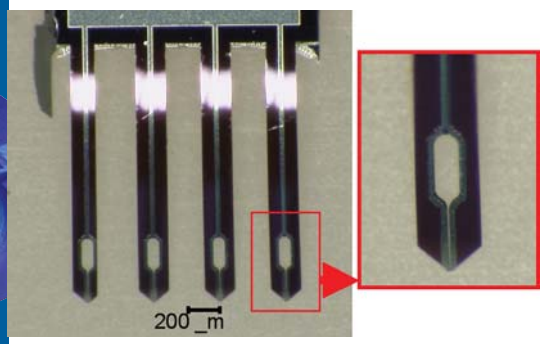
We develop electromechanical nanosystems used as nanotools capable to deposit ultra small volumes of solutions, image surfaces, or measure forces and stresses at the nanoscale. We fabricate arrays of cantilevers working in parallel. Using Nanofabrication techniques these systems are miniaturized in order to increase their sensitivity for actuating or sensing. Integrated piezo-electric actuation and piezo-resistive detection are developed. A fully automatized Nano-spotter for depositing liquid solutions is under development. This instrument is crucial for the nano-addressing activity since it will enable to deposit small quantities of solutions containing diluted nano-objects on prefabricated nanodevices. Resonant mechanical nanosystems are also developed for sensing specific molecular hybridations at a level of sensitivity close to a few number of molecules. The miniaturization of these devices at the nanoscale is under progress.

Development of emerging Nanopatterning techniques

The group is strongly involved in the development of nano-patterning methods of low cost and high throughput. Ultra high resolution electron beam lithography is coupled to Nano-Imprint lithography. We also develop the Micro-contact printing technique for depositing active biomolecules on a surface.

The group is an important actor of the development of the Nanotechnology platform of the technological facility TEAM of the laboratory.





(b) ***Optical profilometry of an array of membranes (300 µm and 600 µm) equipped with piezo actuation and detection. Typical array of cantilevers of the nano-spotter***

LAAS, Laboratoire d'analyse et d'architecture des systèmes, Toulouse

CEMES, Centre d'élaboration de matériaux et études structurales,LNMO, Laboratoire de physique de de l'Institut National des Sciences Appliquées Toulouse

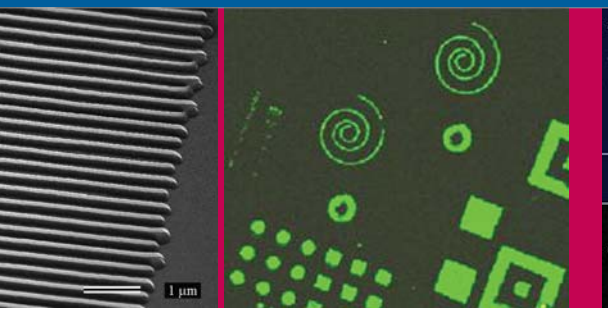
LCC, Laboratoire de Chimie de Coordination, Toulouse

CIRIMAT, Centre interuniversitaire de recherche et d'ingénierie des matériaux, Toulouse

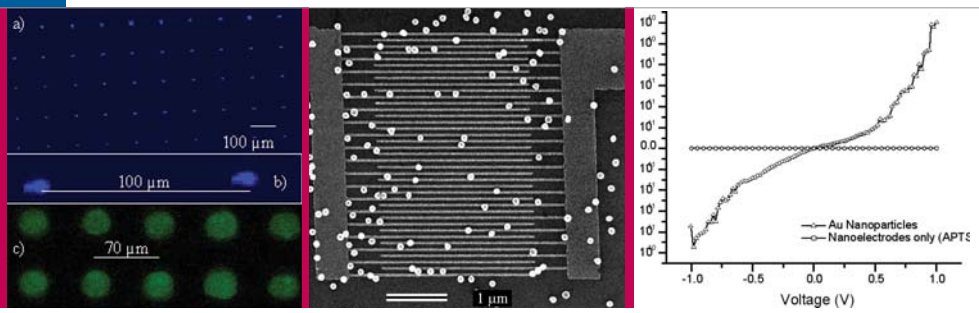
IPBS, Institut Pharmacologie et Biologie Structurale, Toulouse

Genomic platform of the genopole : Centre de Bioingenierie Gilbert Durand, Département de Génie Biochimique et Alimentaire de l'Institut National des Sciences Appliquées Toulouse

LIMMS, Laboratory for Integrated Micro-Mechatronic systems, Tokyo CNRS-IIS



imprinted in a curable material, right side: micrometric patterns of fluorescent antibodies deposited by µcontact Printing.



(d) ***Left side : Fluorescence optical imagse of patterns of protein spots deposited with the nano-spotter. Middle, interdigitated electrode based nanodevice after interaction with biomolecules labeled with gold colloids. Right side, electrical response of the nanodevice after interaction with the labelled biomolecules.***

Nanobiotechnologies

Bio-patterning at the nanoscale and nano-addressing biomolecules will be the two main centers of interest of the group in the wide domain of nanobiotechnologies. In strong synergy with the Genopole organization we develop new technological building blocks combining nanodevices and nano-tools with biomolecules. Two types of elementary projects are developed: the deposition of biological solutions on surfaces with high spatial control and without denaturation and the integrated detection on a wafer of specific biomolecular hybridations for advanced biochips (DNA and proteins). Indeed, the development of various types of biochips involves the deposition on a substrate of a pattern of different biological solutions with high spatial resolution and without denaturation of the biomolecules. In order to meet these requirements, we develop soft deposition techniques using mechanical contact or ink injection. On the basis of an automated array of cantilevers we built a nanospotter capable to pattern a slide with less than 1 µm diameter spots. Contact modes or non contact electrical field assisted depositions can be achieved and are evaluated with respect to biological response. High resolution Microcontact printing of proteic patterns using hard stamps of PDMS obtained by mold assisted lithography is also under investigation.

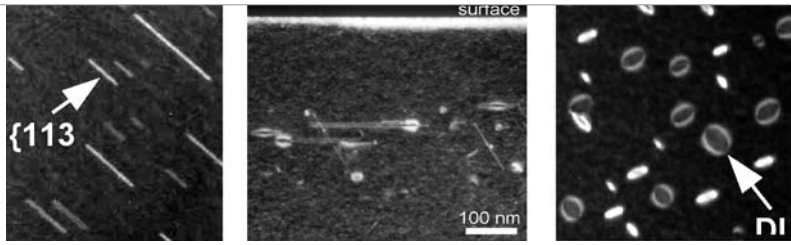
Collaborations

Nano-objects under investigation are generally elaborated by local partners : nanotubes (coll. CIRIMAT), biomolecules (DNA, proteins, coll. Génopole LCC, IPBS), dendrimers (coll. LCC), spin transition molecular compounds (Coll. LCC), self-assembled nanoparticles (coll. LCC). Advanced studies on transport properties in these nano-objects are done in collaboration with LNMO. The investigation of MEMs for biopatterning and biodetection is carried out in collaboration with LIMMS.Nanotechnologies is a cross-disciplinary activity that requires a collaborative effort. Our group is thus working in strong synergy with excellent partners that are the Genopole of Toulouse and more specifically the genomic platform, and different groups of CEMES, LAAS, IPBS and LCC.

The group is strongly involved in two European projects of the 6th PCRD in the "nano" priority : NAPA – Integrated project on NANOPATTERNING and NANOtoLIFE –Network of excellence on NANOBIOTECHNOLGIES.

Technology, Micro and Nanostructures

The activities of the Technologies, Micro et Nanostructures (TMN) group, created in 1999, include the manufacturing processes of materials and interfaces, their properties, their compatibility, the development of innovating structures and components, meant for well defined functions.



Observation with an electronic microscope of dislocation loops linked to an implanted zone à une zone implantée

The development of microsystems requires the availability of various technologies and materials, different from those which are used in traditional microelectronics, in particular CMOS. Besides, application fields of microsystems are numerous and imply heterogeneous elementary functions – actuation, transduction, detection, measuring,… - and also use new materials, or materials having unwell known properties, as far as thin layers and interfaces are concerned: thermal, mechanical, optical or electrical. Microelectronics itself has reached limits as far as integration is concerned, the new forecasted solutions, meant to increase performances, requiring non conventional materials and nano-structured and functional interfaces, which do not have yet any established properties or manufacturing processes.

At present, we deal with the following topics:

Technology, study of materials and development of processes

ULTRA SHALLOW JUNCTIONS

The permanent miniaturization of MOS transistors implies, on the one hand reducing the deep extension of both the *source* and *drain* junctions down to a few dozen nanometers and, on the other hand, increasing their doping up to the dopants solubility limit. This raises, first, new technological problems, such as low-energy implantation, ultra quick annealing, substrate preamorphization, but also physical ones, such as abnormal diffusion of dopants, their deactivation and their precipitation. Two studies are presently conducted on these problems: **interaction of defect dopants** and **precipitation/deactivation of dopants.**

SILICON DEPOSITION PROCESS

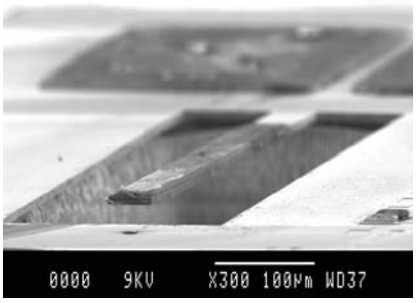
Studies conducted in the laboratory, in collaboration with the chemical engineering laboratory, are focused on developing processes for low pressure chemical vapor deposition of silicon. We work on different types of reactors, i.e. "tubular with perpendicular flow", "parallel flow" and "plasma assisted", so as to explore a wide range of LPCVD deposition parameters while retaining a good homogeneity and reproducibility of the layers. Studies have been thus started on the four following topics: **fundamental phenomena on the growth of non-doped silicon, SiO_xN_ysilicon oxynitride deposition, boron highly doped silicon deposition (Si :B),** and **silicon nanocrystals.**

MATERIAL CHARACTERIZATION

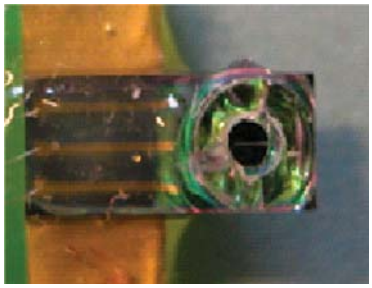
The aim of this study is to enable access to mechanical properties, only known for mass materials, in order to answer the questions raised by the circuit designers faced with the mechanical problems of the power components. When functioning they can produce a significant temperature rise, making knowledge of the thermal and mechanical parameters necessary.

Technological path for microwave frequency microsystems

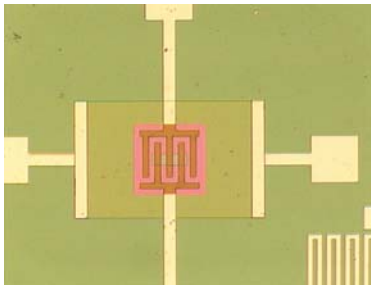
The field of microwave frequency electronics has known a spectacular development in the last ten years, due to the generalization of mobile



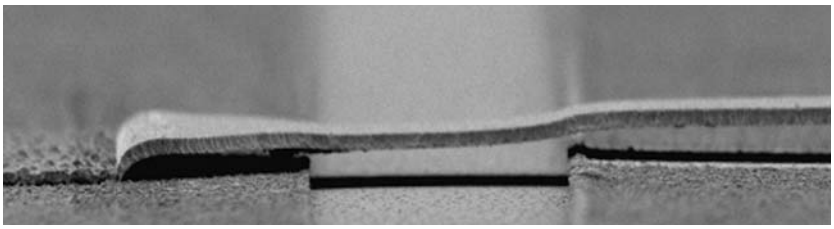
Integrated Si-Cu thermal switch measuring the temperature of the expansion coefficient of Copper



Microtank (1 µL) integrated on an ISFET chemical sensor



Gas-sensor: LAAS Microhotplate and WO3 sensing layer from L2MP



View of part of an electrostatic actuation bridge

communication, which require miniature, high-performance, reliable and low-cost microwave frequency electronic systems. These constraints imply developing new adapted technological paths for which silicon seems to be the choice material, in particular due to its micromachining qualities. In this context, we therefore work on the development of high-performance and reliable microwave frequency microsystems. The present study fields are: **suspended circuit path** and **path for electrostatic actuation metallic microbridges.**

Chemical sensors

In many fields, such as health, environment, agri-business, cosmetics, home automation, automobile, … demand for safety and security is regularly increasing. The result, among others, is an increased need for detection, measure and analysis of various chemicals. The development of microsystems is the main answer to this evolution, particularly if they include electronic sensors, integrable and directly interfaceable with signal processing circuits, which will enable real-time measuring and command/control actions.

Our studies on this subject concern the development of **field effect chemical microsensors (transistors and capacitors)** and **gas microsensors made with semiconductor metallic oxides.**

Reliability of non-volatile memories

This study originates from the necessity of defining new analysis procedures and reliability tests because of special requirements of some applications such as long lifetime, high reliability level and high volume production. Another problem is reducing the cost of reliability tests. The work done concerns data retention of non volatile memories embedded within a "Smart Power" circuit. A new data retention test has been suggested, which would reduce by some decades of time the duration of such an analysis.

Economic development

The group is also concerned with the question of economic development, and the present work concerns pressure sensors and radiation sensors. For pressure sensors, the group studies the designing, development and characterization of sensors requested by a specific small company. As far as radiation dosimeters are concerned, we work here, in the framework of a patent license and a means renting contract, on process and characterization support for a small company manufacturing dosimeters in the LAAS technological facility.

See recent publications at the following address:
http://www.laas.fr/laasvf/index.htm

Microsystems and systems integration

The activities of the MIS Group are dedicated to the development of methods, tools and technologies for the integration of systems and multifunctional microsystems. In response to scientific and technological demand, the MIS group has focused its activities along two main orientations:
>> Injection of technological and conceptual advances : by contributing the basic scientific tools indispensable to the development of technologies. The preferred route has been to use modelling at the atomic level, concentrating our work on new ideas for embeddable devices and on the new technologies relating to 3D integration and production.
>> Forging the tools for achieving the transition from components to systems, using an approach which ranges from virtual prototyping and multi-sensor processing, to hardware prototyping.

This work is undertaken in the context of French (CNRS , Ministère de la Recherche : RNRT, PREDIT, ACI), European and international (MEMSOI, Micropyros, AtomCAD, Hike, Awake) research programmes or in the context of direct collaboration with companies.

Integration technologies and innovative concepts

MODELLING OF PROCESSES AT THE ATOMIC LEVEL

The reduction in size and the mixing of technologies demand ever deeper knowledge of the physical mechanisms responsible for the performance of components and heterogeneous assemblies : our ambition is to develop tools based on analysis and modelling at the atomic level, which can be used for the design of new generations of components. Current studies are investigating the oxides in microelectronics « ultimate MOS » and nano-biotechnologies.

FLUIDIC MICROSYSTEMS

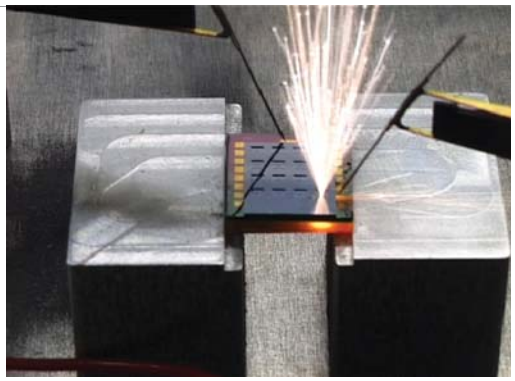
The overall ambition is to provide the methods and tools for a new generation of integrated fluidic microsystems. The applications aimed at are biological analysis and chemical synthesis processes. Our main effort is currently focused on integrated ejection heads and multifunctional systems of the Lab on Chip or Fab on Chip type. The technological choice adopted for the latter, is the hybrid integration of systems (polymers/silicon) using SU8 photosensitive epoxy resins.

PYROTECHNIC MICRO MOTORS

This technology is used to convert the internal chemical energy contained in propellants into electrical, mechanical or thermal energy. Three types of pyrosystems are currently being developed: gas or pressure wave generators, boosters to generate mechanical forces and « secure » pyrotechnic microdetonators on silicon.

DIGITAL MICROMIRRORS

This activity, initially studying sweeping operation for robotic applications, enabled the development of a variable deflection mirror technology and its associated control electronics. This activity is currently investigating digital operation, i.e. all or nothing. The intended applications are optical switching of light beams, in particular in the field of telecommunications.



Array of microthrusters during combustion

ON-CHIP ADDRESSING SYSTEM FOR THERMAL ACTUATORS MICRO-ARRAYS

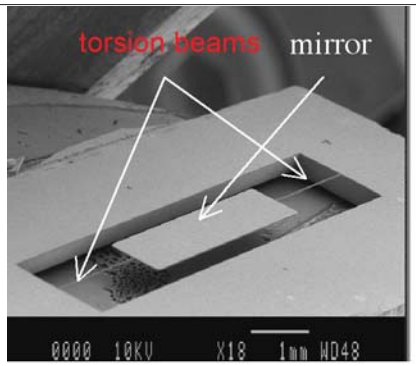
This point introduces a generic nature to the design of addressing systems for microsystems but is of very direct concern to our applications for pyrotechnic motors and matrix nozzles. The idea is to combine a matrix arrangement of micro-objects with a threshold element and electrical routing ensuring exclusive addressing of the selected cell.

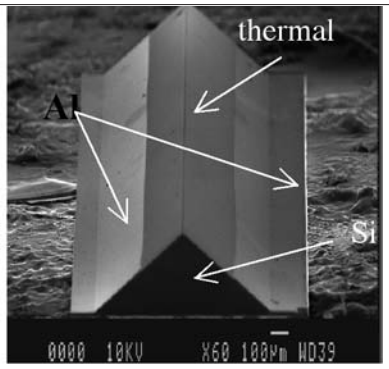
MICROTOOLS FOR SURGERY

This project concerns robotic and remote-operated laparoscopic surgery. It is exploring the potential offered by microtechnology in order to develop articulated forceps incorporating electronic lighting and a micro-machined silicon load sensor.

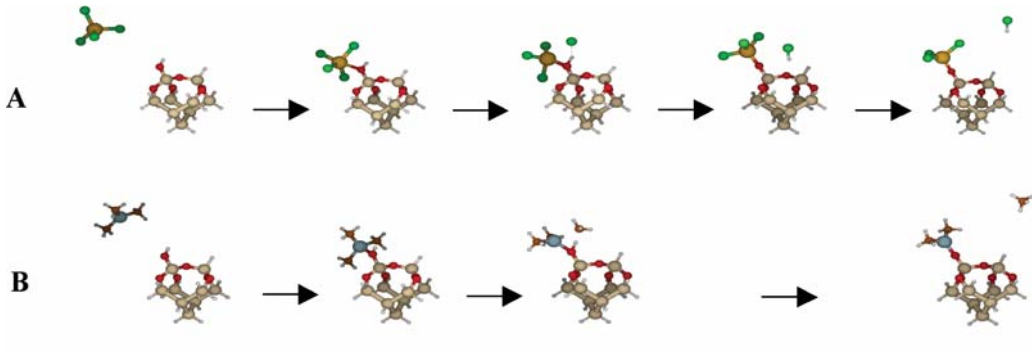
ASSEMBLY TECHNOLOGIES

Work is in progress on 3D assembly of heterogeneous components. This work has already led to the assembly of electronic standard "bare





Silicon micromiror a) upper part *b) lower part*



Dissociation mechanism of $HfCl_4$ on SiO_2 (case A) and $Al(CH_3)_3$ on SiO_2 (case B)

chips" or of chips thinned down to a few µm. It is now concentrating on the development of generic processes for fluidic microsystems.

Systems integration

One of the characteristic features of microsystems is the complexity and the strongly heterogeneous nature of their constituent components. Our strategy is based on the elaboration, prior to materialisation, of a virtual prototype, which can incorporate the modelling and the specific multi-sensor processing algorithms, and capable eventually of incorporating the prediction of failure mechanisms.

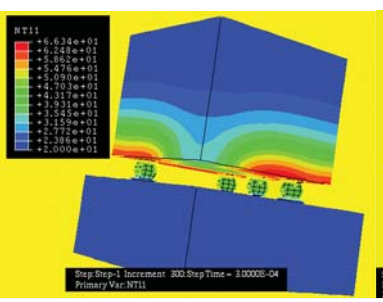
VIRTUAL PROTOTYPING AND RELIABILITY PREDICTION FOR MICROSYSTEMS

This work involves the incorporation in a simulator of behavioural or physical function models (electrical, mechanical or thermal) and includes injection into the virtual prototype, of failure mechanisms. This approach was used for the integration of an IR imaging system and is now being extended into the field of vision and image recognition systems and home surveillance devices.

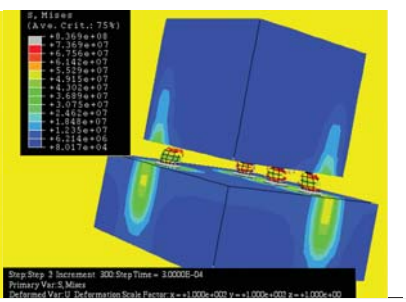
MULTI-SENSOR PROCESSING AND SHAPE RECOGNITION

The processing of multiple sensors is an important axis in microsystem applications. This procedure involves learning techniques and in certain cases artificial intelligence networks, which are highly suited to integration on silicon. This very horizontal activity concerns many application sectors in the Group : vision systems, surveillance systems.

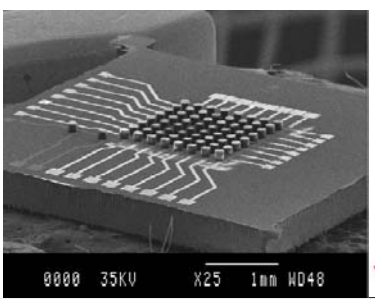
Thermomechanical behaviour of a chip mounted on an aluminium nitride (AlN) sub-layer by the "Flip Chip" technique:



(a) thermal response



(b) mechanical stresses induced and location of the danger zones.



Plan view of an array of microejectors

CNRS Laboratory for Analysis and Architecture of Systems

System Engineering and Integration

System Engineering requires the pooling of various and varied models known as "trade models". In such a context, the first aim of model integration is to make connection and dialog between the trade models of system engineering easier. The other objectives are the investigation of system design approaches, the search for validation and verification means and studying how models could interoperate. The ISI team is involved in studies concerning integration models in three interrelated directions: heterogeneous systems modeling, model integration in the field of requirements and design engineering, and distributed simulations.

Heterogeneous Systems Modeling

Studies on this topic are based on software engineering standards, such as UML *(Unified Modeling language)* and MDA *(Model Driven Architecture)* and, on the other hand, on the team's expertise on formal models, such as Petri Nets (PNs), continuous systems and hybrid systems. The principles of MDA enable us to separate functional specifications from detailed design specifications. It results in a structuring of the modeling and aims at a transparent use of the same models for a sequential simulation or a distributed one.

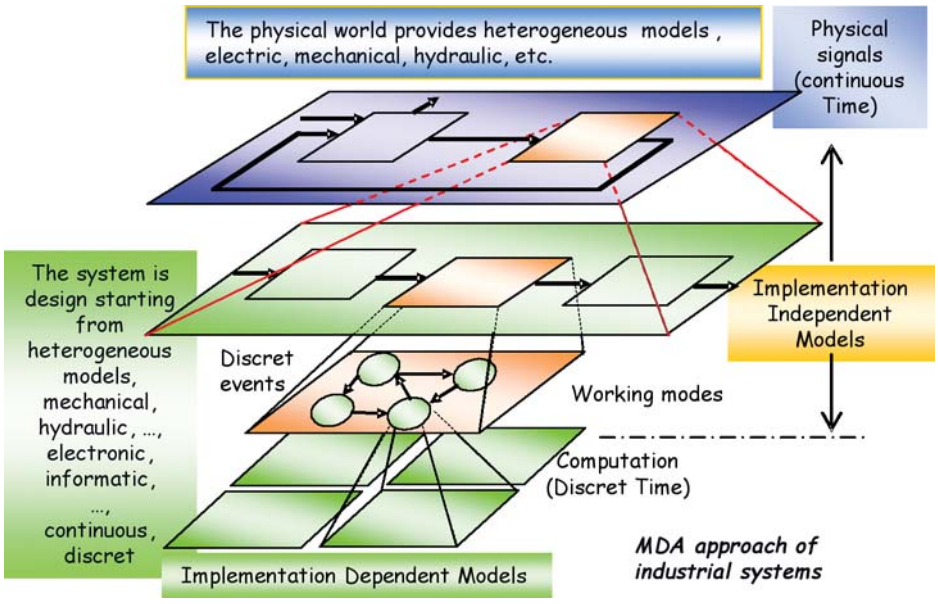
UML language, seen as a meta-model able to express heterogeneity, has many extension possibilities. We use it to define an UML/PNO approach for the design of real-time embedded systems, in which Petri nets are used to formalize object behavior and come in addition to UML for the breakdown and structuring into sub-systems.

Model Integration

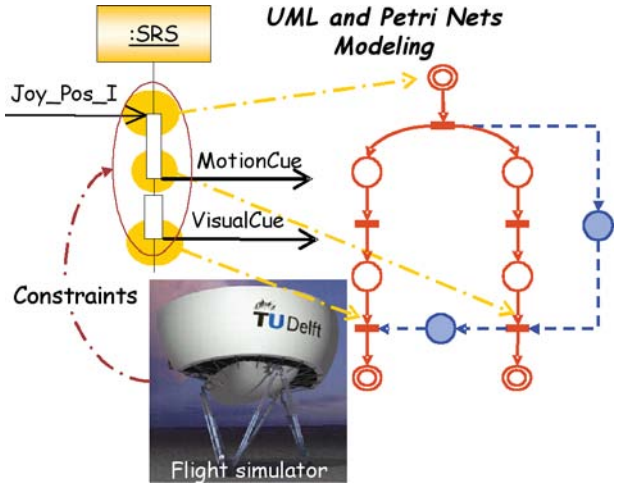
Two types of model integration are considered; on the one hand UML and Petri net integration, i.e. a semi-formal language with a formal model, on the other hand Petri nets and algebraic-differential equations (EAD), i.e. two formal models.

INTEGRATION OF UML AND PETRI NETS

In this case, the chosen integration approach is a translation approach (production of a unique model from several UML models). The UML/PNO method has been defined in this way to help the designer



Heterogeneous Systems Modeling



Integration of UML and Petri Nets

Actions and Applications

For industrial applications, integration of Petri nets and DAE has enabled us to analyze the security of mecatronic systems in the automobile industry (in collaboration with PSA Peugeot-Citroën).

The ISI team also takes part in technological exchanges, in particular in the context of the PISE project (Energetic Systems Integration Project). It conducts the *Embedded Computer and Electronic Systems* group of the RT3 network (Inter-Regional Network for Technological Research on Land Transports).

Finally, it takes part of the LAAS project of an upstream design platform for heterogeneous system development.

validate and check the models and the coherence from one model to another.

To study the temporal aspects of the system, the UML/PNO method also uses the Girard's linear logic, to check as early in the development process as possible the temporal needs of the analysis and design models. This extension allows a component approach for structuring and a scenario approach for evaluating temporal needs. We also use an evaluation technique based on the [max, +] algebra.

INTEGRATION OF PETRI NETS WITH DIFFERENTIAL ALGEBRAIC EQUATIONS

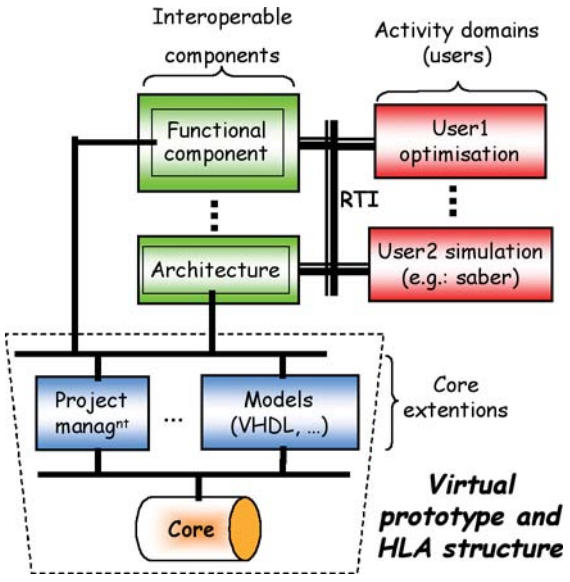
Initially developed for the control of *batch* processes, the integration of Petri Nets with differential algebraic equations (DAE) allows joining the two aspects, discrete and continuous, inherent to the complexity of the physic-chemical processes and their different functioning configurations. We chose two different formalisms because we wanted to use all the possibilities offered by the trade models of physics and chemistry and by automation specialists in the discrete modeling field.

To retain all the potentialities of each involved model, we chose integration by coupling: association of the DAE with the place of Petri net DAE and formalization of the continuous-discrete translation. We can thus identify a first set of properties for each one, so as to check which of their own properties have been kept or lost in the integrated model, and also if new properties have been added.

Simulation and System Control

The interesting outcome of a simulation is not only the results, however quickly they may be obtained, but also the fact it allows to quickly compare the respective interpretation of the needs of analysts and users. Moreover, distributed simulations enable us to connect several simulators and perform a multi-model simulation tools.

In this context, the team has introduced the notion of virtual system, which allows encapsulating simulators and models. The structure of virtual systems enables us to deal with the connection of



Simulation and System Control

heterogeneous simulators and models. As distributed simulation architecture, we use an approach based on HLA *(High Level Architecture)*, which allows the simultaneous execution of trade models and subsystems. Management of the simulation timing is based on the conservative synchronization method.

Qualitative Diagnosis and Supervisory Control

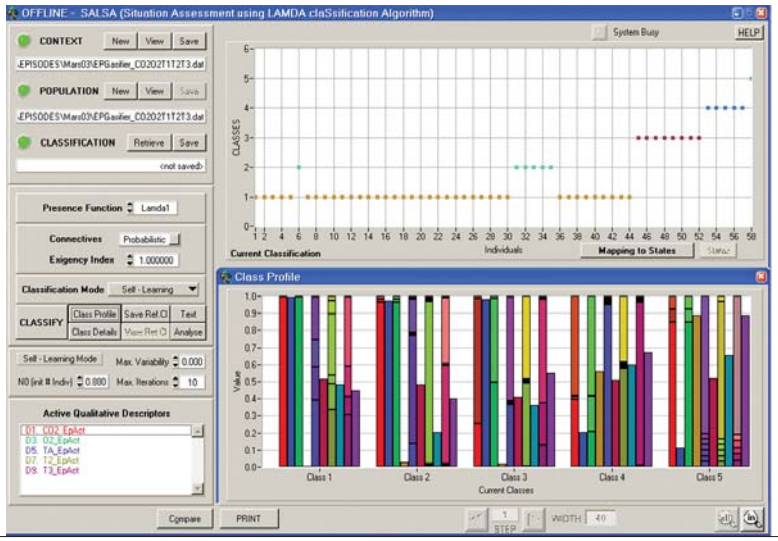
The group research lines are the following:
>> Model based Diagnosis and reconfiguration
>> Monitoring and Supervision based on learning and pattern recognition approaches
>> Supervisory fault tolerant control of non linear systems

The DISCO group develops diagnosis and supervision tools for complex dynamic systems, possibly including human operators. We stress the qualitative nature of the data that is relevant to supervision in resonance with the continuous aspects of the systems. Hence, hybrid systems and the interface between continuous signals and their interpretation in terms of discrete events are at the core of our activities. The qualitative nature of knowledge and the uncertainties tainting the data induce us to call on qualitative and symbolic formalisms originated from Artificial Intelligence as well as on machine learning and pattern recognition methods.

Model based diagnosis and reconfiguration

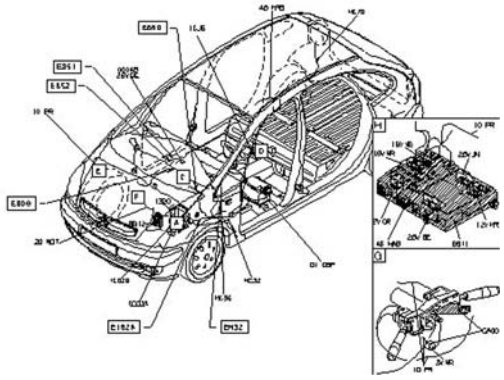
Diagnosis can be defined in a broad sense as a set of three tasks: fault detection, isolation and identification. Diagnosis is of prime necessity in many application domains, for instance for monitoring of industrial plants or in the space domain for increasing the autonomy of spacecrafts. Our contributions are both for off-line and on-line diagnosis. Most of our case studies consist of dynamic systems whose models may be spread out in continuous, discreet or hybrid state spaces. The group's background work addresses modelling and qualitative reasoning, comparing the approaches from the Control and the Artificial Intelligence communities, analysing diagnosability. In other respects, the following projects are representative of recent research topics developed in the DISCO group:

■ Automatic generation of optimal diagnosis trees for off-line diagnosis: this problem is solved by a heuristic search method (AGENDA prototype) complemented, during the tree traverse, by a qualitative model based diagnosis method accounting for non anticipated faults. This work finds a preferential application in the automotive domain in the framework of the Common Laboratory AUTODIAG, in partnership with two neighbouring entities which



(1) Functional states recognized by LAMDA

(2) On-board state-tracking and reconfiguration based on uncertain hybrid models. Application to a subsystem of the Spot 5 satellite



(3) Diagnosis in the automobile domain. Test points

are the ACTIA company and the research laboratory IRIT. (3)

■ On-line diagnosis and reconfiguration of uncertain hybrid systems: the proposed hybrid model (KOALA formalism) integrates concurrent automata whose states represent the component operating modes and bounded uncertainty continuous models. The approach relies on a logic representation — called *configuration* — of the different state space regions, which makes possible the extension of the existing logical theory of diagnosis. The devised diagnosis engine interleaves progressive search in the hybrid space and consistency checks, making use of truth maintenance and propositional satisfaction techniques. This work was illustrated on the Attitude and Orbit Control system of a SPOT satellite case study in collaboration with CNES and ASTRIUM. (2)

■ Distributed supervision of complex discrete event systems approached from the two following perspectives: model distribution in the form of a set of Petri net models designed according to the physical organisation of the system; distributed monitoring based on event models expressing temporal constraints under uncertainty related to communication delays.

Monitoring and Supervision based on learning and pattern recognition approaches

This research line aims at devising multisensory fusion tools providing the operators of industrial plants or other artefacts with easy-to-interpret information in normal operating conditions as well as in faulty situations. The problem consists in interpreting a set of continuous signals in terms of "operating modes" that have a meaning to the operators and/or to generate directly a performance/criticality index corresponding to the current state of the system. The tools must be consistent with the mental representation of the process that the operators draw up, which calls for interactive tools.To build these tools, we call on signal and image processing methods which are able to extract relevant events, and on the other hand on classification and pattern recognition methods to characterize the functional states of processes, possibly on-line.

We position ourselves as users of classical statistical classification methods, decision trees, neural networks, fuzzy algorithms like "c-means". However, our efforts are focused on the development and enhancement of the classification method LAMDA that was devised in the group and includes useful features for combining quantitative and qualitative aspects.

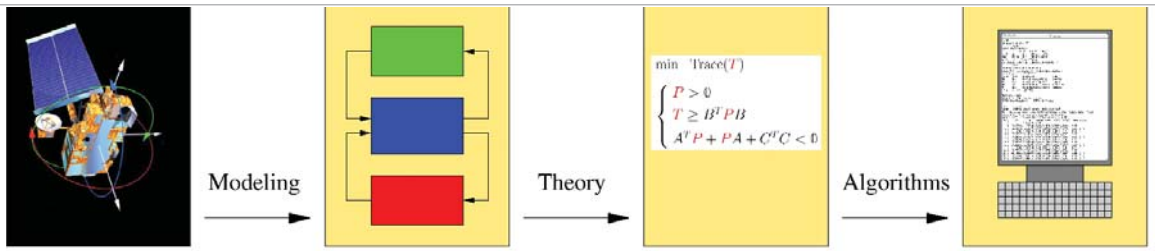
LAMDA was recently applied to petrochemical processes in the framework of the European project CHEM coordinated by IFP. (1) In another project, LAMDA is used, possibly combined with fault detectors implemented by non linear observers, in the domain of waste water treatment.

Supervisory fault tolerant control of non linear systems

The need for a supervisory control loop, supervising the low-level control loop exists when the system is far from standard cases, linear or of low dimensional complexity, also in faulty situations. The DISCO group conducts recognized activities in research domains that are linked to process control, like Takagi-Sugeno fuzzy control, or non linear inverse control which are turned to good account in supervisory control schemas. A great deal of our activities in this research line considers problems in the aeronautic domain, from traffic problems on the ground or in flight to aircraft control problems. This work can be illustrated by the applications in the framework of two collaborative projects, one with CENA on aircrafts relative navigation, and the other with EADS-Airbus Industry on automating the control of aircraft ground taxiing operations.

Methods and Algorithms in Control

The activities of the "MAC" group are centered on the field of Control and System Theory, through studies on modeling, estimation, performance analysis and control of dynamic systems.



Approach

Starting from a continuous-state model, linear or nonlinear, stationary or non-stationary, and possibly subject to delays, research focuses on systems (launcher, satellite, water treatment plant, communication network, robot, etc.) for which:

1. The model is subject to uncertainties, explicitly taken into account for the control law design through various mathematical representations (polytopic, norm bounded, affine, fractional, …),

2. The dynamics imply nonlinear elements due to the very nature of the system (actuator, sensor, …) or to the action of the undertaken control laws.

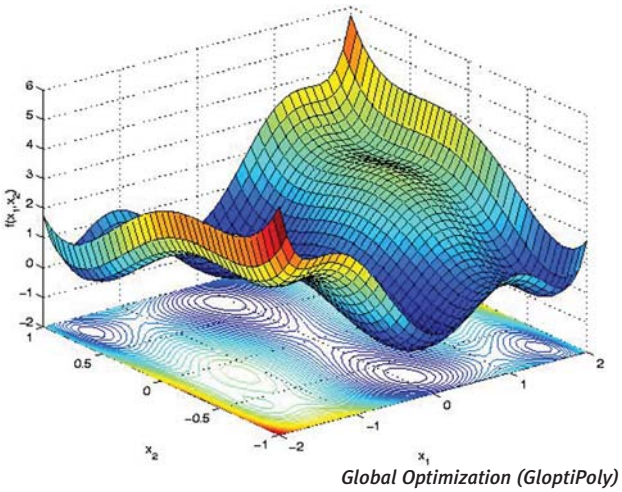
The main idea is not only to express the theoretical conditions which characterize the solutions to the various problems, but also to provide efficient algorithms, most of them deducted from optimization problems, formalizing in the specifications the desired functionalities.

Therefore, the group studies are centered on two main subjects, **Robust Control** and **Nonlinear Systems Control**, the shared tool being optimization.

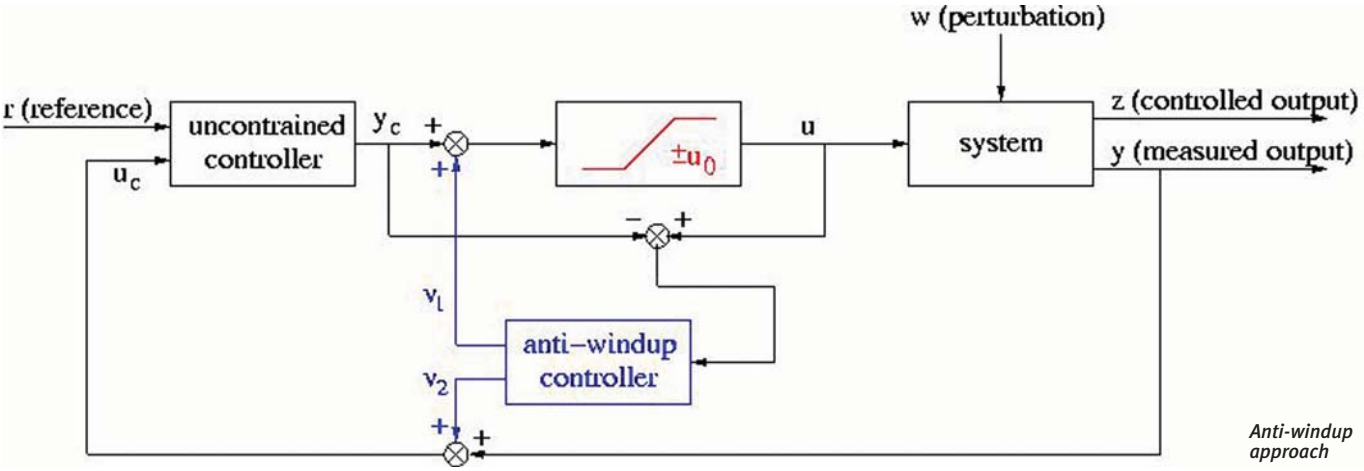
Robust control

The aim of robust control is performance analysis, control design and state observation of uncertain dynamic systems, submitted to a noisy environment (random or not).

The central points which are structured (decentralized) control laws synthesis and static or reduced-order dynamic output feedback (embedded systems) are for us a permanent research topic. The different techniques are developed as well in state-space as in a polynomial context and mainly address the framework of multi-objective design (mixed H_2 / H_∞ / impulse-to-peak). To deal with the compromises needed to reach a solution, we evaluate the pessimism of the



Global Optimization (GloptiPoly)



Anti-windup approach

analysis and synthesis methods (due to structured uncertainty and quadratic separation) so as to reduce it. One related question, in the context of control law implementation, lies in the fragility/resilience of the controller, which coefficients are necessarily approximations of the computed ones. An investigated solution to the problem is to determine a continuous set of admissible controllers so as to allow uncertainties on the prescribed one.

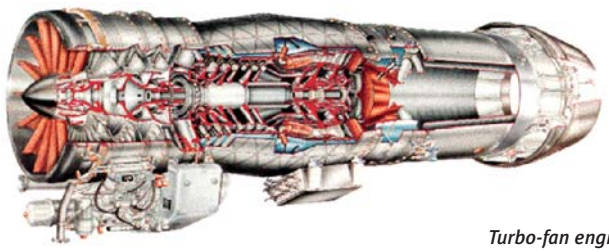
The development of robust control methods and specific tools goes with the development of algorithms and software interfaces based on semi-definite programming. We therefore investigate optimization techniques, in particular global optimization (see for example, the GloptiPoly software).

Nonlinear systems

We do not study nonlinear systems in general, but focus on a certain class of nonlinear systems offering obvious practical interest.

Using a quasi-LPV approach, nonlinearities are studied as varying parameters, which variations depend on the state of the system. Starting from a nonlinear model, we define a gain sequencing robust control policy around transient equilibrium points specified to reach trajectories coherent with the operational constraints (domain of evolution, speed, …). This type of technique is particularly useful for turbo-fan engine control (cooperation between LAAS and SNECMA), as the nonlinear model integrates all mechanical, thermal and thermodynamic phenomena.

In the same way, actuators belong to a special kind of nonlinear systems. Generally speaking, they are dynamic systems which own requests have to be controlled, so as not to impair the functioning of the closed-loop control systems which they are part of. It is therefore important to take into account the saturation, both in position and speed or more generally on the actuator dynamics. Dealing with the problem of domain analysis of a closed-loop system secure functioning with different kinds of saturating actuators implies developing more relevant methods. This type of problem mainly exists in


Turbo-fan engine

aeronautical contexts (high agility of combat aircrafts), spatial contexts (guidance and robust piloting of launchers) or biological contexts (control of equalization systems). Taking a larger view than the mere analysis problem (assuming a known controller), a very promising approach would be to modify the controller or to add a complementary loop (anti-windup problem) so as, for example, not to impair (not too much anyway) the expected performances in spite of actuator saturation.

Moreover, studies on the structural properties of the system (reversal, control and access capabilities) are necessary to assess the existence of control laws providing various performances (stability, tracking, …).

Modeling, Optimization and Integrated Management of Activity Systems

The research activity of the MOGISA group focuses on studying systems in which activities must be executed by resources. The execution of activities is subject to constraints related to the use of resources and to the execution of projects or processes. One of the main characteristics of the application fields (project management, management of production systems of goods or services) is that they are highly socio-technical, i.e. man remains at the center of the activity systems, often assuming a variety of roles. This justifies our aim of designing models, methods and tools providing support to analyze, evaluate, design and implement complex systems in an uncertain and disturbed environment.

Production Planning

The planning of activities in systems including different decision centers with mutual interaction is focused on multi-level approaches based on data aggregation mechanisms. These approaches enable us to associate to each decision center a decision-support model which will take into account the specificities of each center and also integrate interactions between centers.

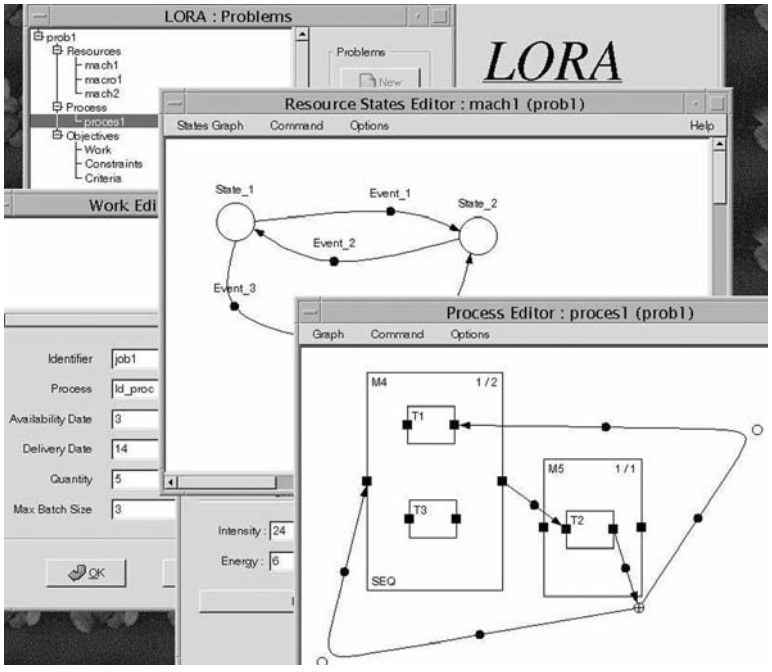
The aim is to bring out the relevant aggregation mechanisms, so as to handle the complexity linked to the variety of the data and their uncertainty. We then need to model each level of the decision structure as its global coherence requires that decisions worked out at one level should be implemented at a lower one. Resolution models and methods are based on mathematical programming, the graph and flows theory, and metaheuristics.

We apply this type of approach to the manufacturing industry (logistic management of production lines and multi-level scheduling) and also to the management of activities in hospitals.

Scheduling

We treat the production line organization problems with approaches centered around representing and exploiting constraints. The aim is to develop tools which will make easier interaction between useful analysis methods in a decision-support environment (consistency checking, characterization of feasible solutions) and efficient resolution algorithms.

Robust handling of a system of activities in a disturbed environment is based on the development of constraint propagation algorithms, allowing to reduce the number of acceptable solutions and taking into account, in an integrated way, scheduling and allocation decisions; it is also based on a predictive scheduling to result in a series of characterized solutions leading to partial execution orders. A decision-support system, including reactive scheduling processes, then allows the organization of a real-time execution of activities.

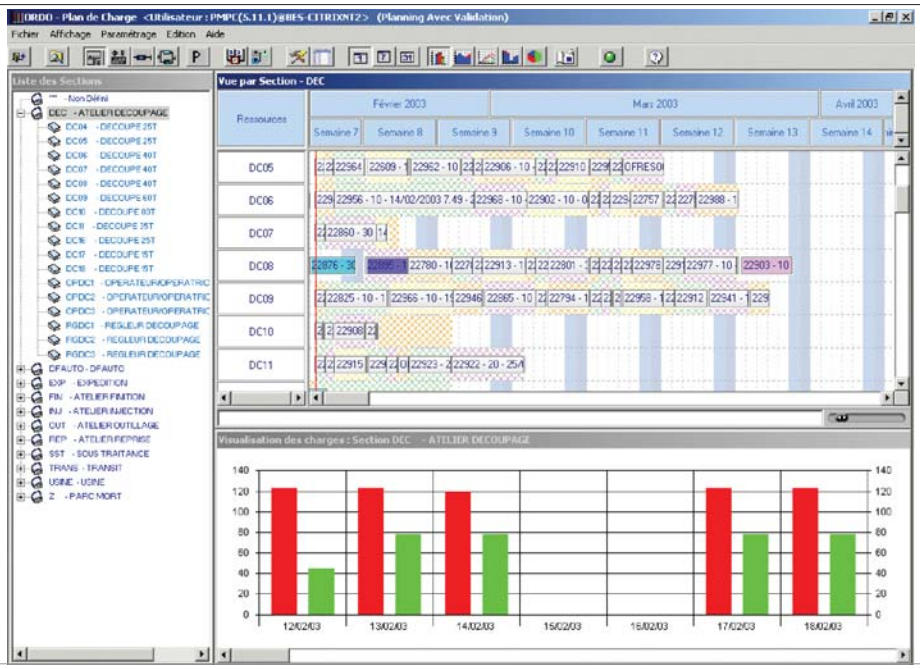


LORA platform

A LORA platform - experimental platform for validating and evaluating the methods of task scheduling and resource allocation - provides a good representation of these concepts.

Combinatorial Optimization

The building and direct resolution of mixed integer programming has allowed us to develop an optimal planning of telecommunications between planet exploring probes and earth orbiting satellites.



Production planning: Gantt chart and resource workload

We also solved different problems linked to personnel assignment in an airport context (establishment of planning grids, assignment of working periods to staff).

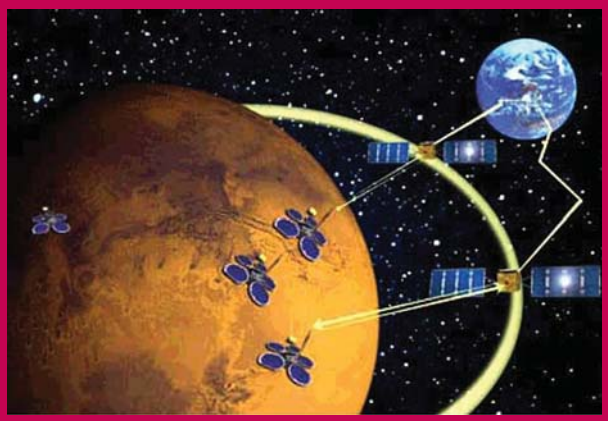
In case of a high combinatorial explosion, we can alternatively use column generation techniques (dividing the initial problem between a main problem, which can be solved with traditional linear programming and a secondary problem which needs the use of graph algorithms).

Cooperation

In this last topic, we try to find what cooperation-support models we can offer to organizations and how to make sure that a negotiation process may lead toward a solution satisfactory to all decision-makers.

In a context of human resources management, we favor a constraint-based model for a limited but objective characterization of the required profiles for each activity and those of the actors. The aim is to make piloting the process and allocating resources easier. The adequacy of static and dynamic characteristics of activities and actors defines a constraint satisfaction problem. The piloting of the process and the allocation of actors constitute a mixed problem of configuration and assignment.

Inter-planet Telecommunications



Telecommunication Networks and Systems

This group deals with the development of new methods and algorithmic approaches, mainly using differential models to analyze, design and evaluate the performances of telecommunication networks and systems. It is also concerned with advanced signal processing and systems modeling and control, mostly applied to the telecommunication field.

The group conducts different research projects on traffic modeling, optimization and network planning, cluster or grid computing systems, particle technique applied to signal (RADAR, GPS and GSM), Volterra filtering, identification via hereditary algorithms and diffusive representation. Industrial partners of the group are: Alcatel, Aérospatiale, Thales, DGA, DCN, Bouygues Telecom, Cegetel, CS-SI, Diginext, Alinka, QoS Design.

1. Analysis, Design and Performance Evaluation of Telecommunication Systems

1.1 PERFORMANCE EVALUATION

This research deals with the modeling of stochastic processes related to traffic within networks (blocking probabilities, end-to-end delays, jitter and possible loss of information).
A first continuous-type approach, based on the differential traffic theory, developed by LAAS in the eighties, allows to precisely represent circuit switching networks and packet switching networks.
As the differential theory does not allow to represent all stochastic processes, we also use a second hybrid modeling approach, combining analytic modeling with event simulation.
These techniques are used for modeling huge operator networks (telephone and IP/MPLS). Particularly concerned are models of multimedia traffic sources, TCP protocol modelling based on the differential traffic theory, and the modelling of IP/Diffserv/MPLS routers.
The recent results achieved in this field are transferred to industry by the new start-up QoS Design (created by the group) through the NEST software (Network Engineering & Simulation Tool).

1.2. NETWORK OPTIMIZATION

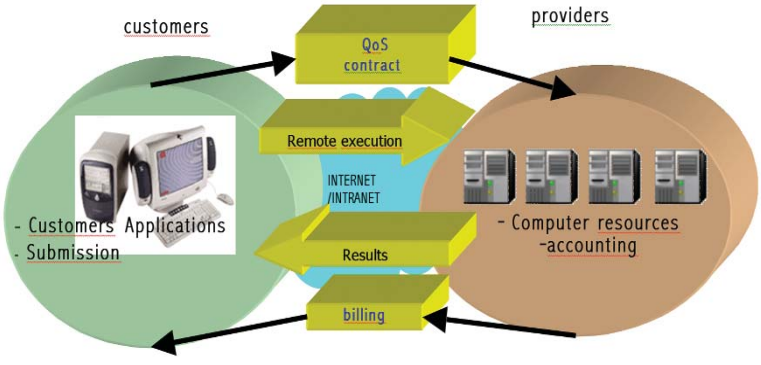
The aim of this research is to study the telecommunication network planning and optimization problems, integrating the different problems faced by an operator (telephone networks and IP networks):

- **dynamic routing of traffic flows** in order to face occasional or seasonal demand variations in telephone networks (flow partitionning, overflowing techniques, routing rules) and in IP networks (metrics optimization, paths optimization)
- **dimensioning** of links and existing nodes, according to the expected demand
- **topology optimization :** design of new networks or extension of existing ones (local loops and secure SDH backbone networks).

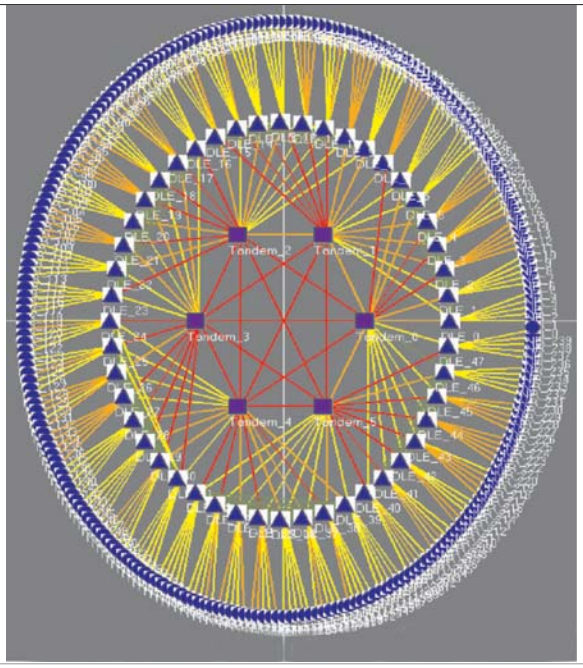
In all three fields, optimization problems are rather complex and mainly combinatorial (non-linearity, all kinds of constraints). For large networks, optimization can be achieved by coupling exact and meta-heuristic methods.

1.3. GRID COMPUTING AND ASP CLUSTERS

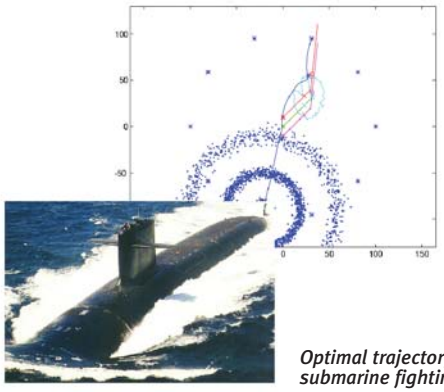
A computing grid allows to coordinate distributed resources, in order to use the computing potential as easily and efficiently as possible. Research is aimed at the modeling of this execution medium and at the parallel, transparent access to, and management of, heterogeneous resources, global supervising of the system, assistance to users and administrators.



Access to clusters through internet



A hierarchical telephone network



Optimal trajectory in submarine fighting

Today, a cluster is the best adapted support for "Application Service Provider" (ASP) services, due to its scalability, modularity, evolution capability and cost. Research is focused on studying the quality of service (availability), billing in accordance with predefined quality, non-repudiation, authentication and confidentiality.
Sun microsystems decided to create an excellence centre at LAAS in the field of computing grids and clustering for applications in telecommunication networks, with partnership of the start-up QoS Design. Research activities are also carried out in the field of parallel algorithms and grid computing (in collaboration with LIFC and LCS laboratories at Besançon). They deal with iterative numerical algorithms using flexible communications, synchronous and asynchronous computing, load-balancing, convergence analysis, stopping of algorithms, especially in case of perturbated operators (for exemple due to rounding errors).

2. Advanced Signals and Systems Processing

This topic concerns the treatment of nonlinear, stochastic and/or distributed problems in modeling, identification and optimization (filtering and control). Applications are mainly focused on the Defense and Communication areas.

2.1 FILTERING

This specific technique is born at LAAS in 1989, as a constructive solution to optimal nonlinear filtering, examining/selecting the different probabilities and using a limited number of particles. Since 2001, the slow convergence ($1/\sqrt{n}$) of this approach has been considerably improved (up to $1/n$) thanks to a determinist interpretation. Patents have been taken for this method, which allow significant improvements in signal processing for RADAR, SONAR, LORAN navigation, GPS positioning, and cellular communications.
The particle technique has been adapted to optimal nonlinear control by randomizing the 'two-point boundary-value problem' into an optimal estimate of the co-state vector. It provides a global optimum to highly non-convex and/or non-differentiable problems, in cases when the usual techniques are not applicable. It is presently used in submarine fighting.
Volterra filtering deals with nonlinear optimal estimators in the class of removable core polynomial functionals. This original tool, particularly adapted to bilinear systems, is used in the electronics war for multi-emission discrimination.

2.2 MODELING AND CONTROL

The diffusive representation is a mathematic tool, created at LAAS in 1992, to analyze, control and estimate systems involving pseudo-differential or integral operators. Its main property is to enable a suitable state representation in an adapted topological space of complex dynamic phenomena inside which functional and numeric analysis tools can be applied. Among other convincing applications we can mention the control of transient behavior of the current in electrical machines, the passive control by means of transparent boundary for propagation systems, or else robust control in the 'pseudo-invariance' sense, a new concept precisely based on diffusive representation.
The research group is a coordinator of a thematic action on the topic (www.laas.fr/gt-opd), sponsored by the national research institutions.

Robotics and Artificial Intelligence

Can a machine be intelligent ? How is it possible to endow machines with sensori-motor and cognitive capabilities which will enable them to understand their environment and act on it? How can we give them the means to learn these capabilities and develop their intelligence? These fundamental questions are the basis of the research conducted by the Robotics and Artificial Intelligence group.

From the group's point of view, a machine is a robot situated in and interacting with a real environment not specifically designed for it. We look at these questions, through a constructive approach, in many contexts and many types of environments, so as to be able to offer generic solutions. The group's studies, both theoretical and experimental, are concerned with the three main fields of robotics: perception, decision and action – to which should be added communication too, in an integrative approach. This poses the problem of the robot system organization – and therefore its control architecture – which has to be furthermore dependable and reliable.

The group's research also aims at understanding and implementing mechanisms enabling the robot to develop its own perception, decision and action capabilities, through learning processes. Finally, even if the robot is autonomous, it also interacts with other robots and with humans. Therefore, one direction of the group's research focuses on designing and developing methods and means to achieve these interactions.

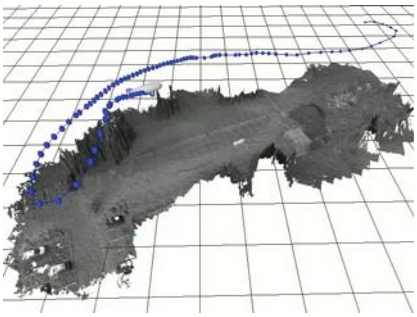
The way to measure whether we have reached these research objectives is through the rationality of the robot behavior obtained. It is evaluated by its performances when faced with the diversity of tasks and variability of environments. It is a rationality bounded by the complexity of time constrained processing, the uncertainty of sensory information, and the incompleteness of models and programs. Performance evaluation, as far as autonomy and robustness are concerned, requires experimental confrontation with a large number of environments and tasks.

Experimental robots in human and natural environments

Integrated projects

In our integrative approach, perception, decision and action are closely related. It is not a 'mere' integration, but the creation of an almost organic link between them, allowing to grasp each function in its relationships with the others – which changes each of them. This integrative approach is precisely why we maintain two internal integrated projects: "Robotics in human environments" and "Robotics in natural environments". Their issues differ by the type of environment, which enables to distinguish different approaches concerning perception, representations, motion planning and execution, etc. Moreover, the first project explores problems of multimodal interac-

Karma robotized blimp and autonomous modeling of ground from aerial images



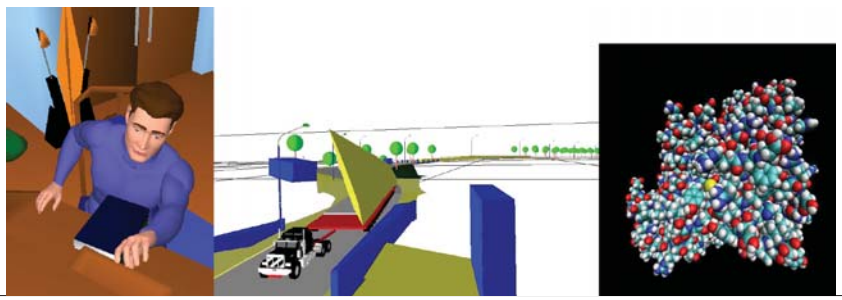
tion with humans, while the second one deals with very different ground and aerial robots (a blimp, called "Karma" has been developed by the group). The two projects have common topics, for example questions concerning control architectures, which allows demonstrating generic aspects as well.

The Robotics and Artificial Intelligence group takes an active part in the animation of research and keeps up regular academic relationships on the international, European and national levels. It is also keen on implementing its results in practical applications in direct collaboration projects with industry or in the context of national or European programs. Indeed, Robotics in its widest understanding, which is the one the group has chosen, can contribute to the answer to social and economical needs. Traditionally, the use of Robotics techniques is motivated by three main reasons: reduction in cost and increase in productivity of a process, hard or fastidious work, and dangerous environments. The group deals with each of these application categories, but two new ones have appeared in the last year, which we started to work on: increase in safety and contribution to the citizens' well-being. This involves, for example, projects on supervision and reaction in crisis situations, surgical robotics, or the issues of robotics in human environments in which

Prototype of laparoscopic surgery robot

robots may be helpers of handicapped or elderly people. And in this type of context, we study problems of robustness and dependability together with other groups of the Lab. In order to be able to pass on its know-how to the industry, the group has recently created a company, "Kineo Computer Aided Motion", to promote its results on the algorithmics of motion planning.

Motion planning: animated characters, the 'Grand Itinéraire' project for the transportation of the Airbus A380 components), molecular docking



Dependable Computing and Fault Tolerance

The research activities conducted by this group concern the **dependability** of computerized systems, which is the property allowing users of a system to justifiably trust the service it delivers. They take place in the context of a continuum between work aimed at advancement of knowledge and work in partnership with the socio-economic sector, meant at producing new services and products.

Demonstrators, tools and partnership

Practical results of the research conducted are demonstrators and tools, among which:

COrBAC: demonstrator of the OrBAC dependability policy for dental surgeries, based on a UML description.

COFFEE: tool for the characterization of failure modes for *CORBA* middleware.

Work is based on continuous partnership with industry, in particular within RIS, the Dependability Engineering Network (Airbus, Astrium, Technicatome and Thales), and several other national and European projects.

Dependability includes various properties, i.e., availability, reliability, integrity, confidentiality, maintainability, safety (against catastrophic failures) and security (against non-authorized access to information). Research deals with fault prevention, fault tolerance, fault removal and fault forecasting, and on the formulation of the basic concepts of dependability.

Fault prevention

Fault prevention aims to avoid the occurrence or introduction of faults. It consists in avoiding design or manufacturing faults and preventing faults during operation. In this context, we develop methods for defining security policies, based on the identification of what properties should be implemented and what rules applications and organizations should abide by. These properties may be conflicting (for example, confidentiality and availability); the suggested policy should try to solve such conflicts in the best possible way. Our current work concerns medical and healthcare applications, which characteristics are their strong need for confidentiality, integrity and availability, and also accountability and privacy. The methods being developed are aimed at the definition of security policies adapted to the wide variety of organizations in which such applications will be implemented (hospitals, consulting rooms, health insurance offices, etc.).

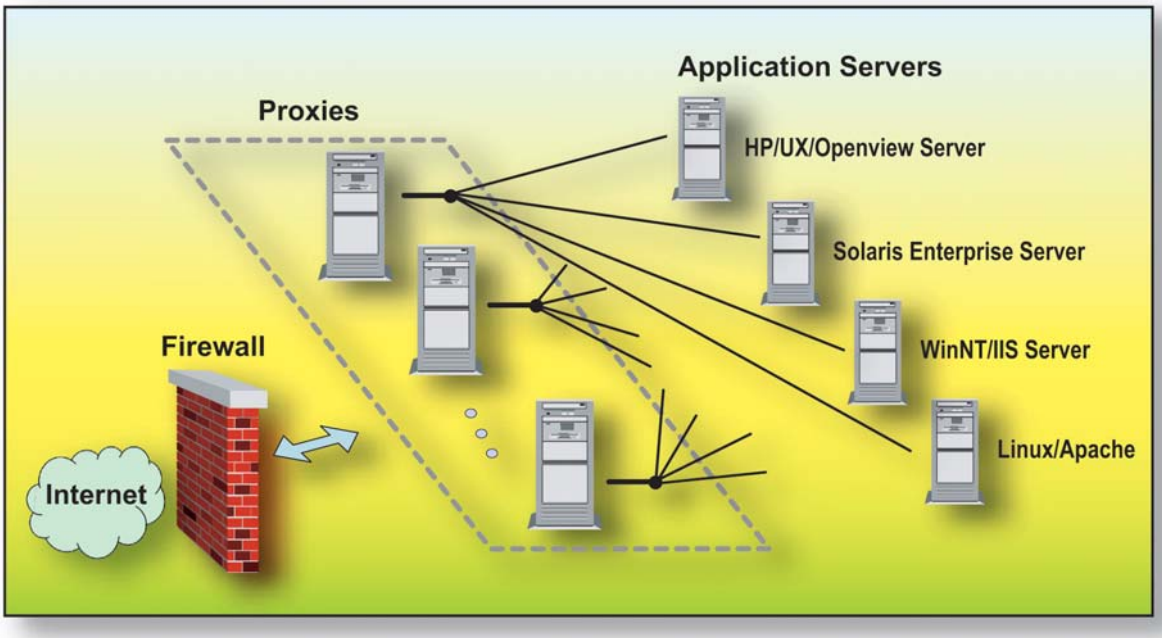
Fault Tolerance

Fault tolerance refers to a series of techniques used to allow a system to deliver correct service in spite of faults. Studies are centered on distributed software techniques for tolerating physical faults, design faults and deliberately malicious faults. They deal with four main working areas:

- Protection of distributed applications on the *Internet*: servers tolerating both accidental and intentional faults are developed using, to the extent that it is possible, diversification of hardware platforms, operating systems and software.
- Use of the reflection principle for a transparent implementation of fault tolerance: a multi-level approach has been defined and a platform developed using standard reflexive mechanisms.
- Wrapping of software executives to provide on-line checking of dependability properties. The latter are specified using a temporal logic modeling of the target software executives. This principle has been used for real-time microkernels and *CORBA* middleware.
- Protection of communications in a network of actuators: this study concerns the future real-time control systems for civil airplanes, and is carried out in collaboration with Airbus. Specific protection means based on error detecting codes have been proposed.

Fault Removal

Fault removal aims to reduce the number and severity of faults. Research is focused on software testing. Recent studies have allowed an extension of the domain of application of statistical testing, which is a method for probabilistic generation of test inputs successfully applied in our earlier work.



Intrusion-tolerant Internet servers, based on diversified adaptive redundancy

They concern three main areas:

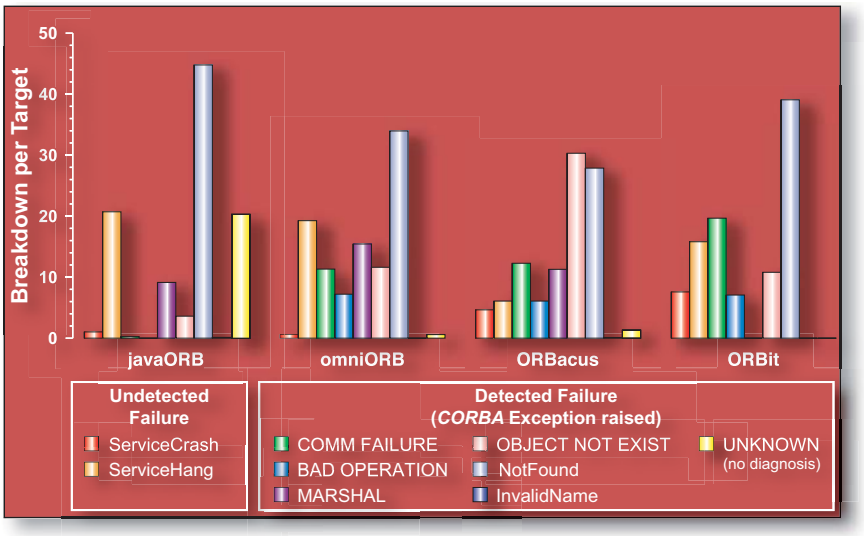
- Test of reflexive software: a strategy of generic and incremental tests, based on decomposition of reflexive properties (reification, intercession and introspection), has been suggested in the context of a project with France Telecom.
- Study of the complementarity between test and proof: a method has been implemented for defining and carrying out tests using information obtained through formal proof.
- Tests with respect to safety properties: optimization heuristics are used to design test scenarios focused on dangerous faults.

Fault Forecasting

Fault forecasting aims at estimating the creation, existence and consequences of faults. Studies are concerned with forecasting the consequences of physical faults, design faults and malicious faults on system dependability. They cover both analytical and experimental evaluation. Present work on analytical evaluation is focused on developing a conceptual framework for hierarchical stochastic modeling of applications developed for the *Internet*. It is aimed at evaluating dependability as perceived by users, in the context of various faults, architectures and usage profiles.

As far as experimental evaluation is concerned, we study two different aspects: failure data analysis and controlled experiments. For the first one, work focuses on developing algorithms and procedures enabling us to use error logs from interconnected *Unix* and *Windows* systems to evaluate their dependability. This study has been focused on the network of computers available at LAAS.

Controlled experiments concern: (a) characterization of failure modes of operating systems (*Linux* and *Windows*) and of *CORBA* middleware, and (b) the benchmarking of the dependability of computer systems. A conceptual framework for defining dependability benchmarks and benchmark prototypes have been achieved.



Characterization of CORBA services by means of interobject message corruption

Software and Tools for Communicating Systems

The studies of the OLC group aim at designing communication software, meant for developing broadband multimedia cooperative distributed applications. Designing such systems implies defining and implementing a set of software components with strong temporal and cooperative constraints, using a very rigorous methodology.

The design process uses formal bases and covers the different steps from specification to implementation, including architecture and behavior description, together with their validation. These studies are divided into three main scientific topics, described hereafter.

Topic 1. Concepts, Formalization and Analysis (CFA)

This topic is concerned with the modeling and verification of distributed, cooperative and time-critical systems. The critical aspect of such systems makes it mandatory to verify them, both on the qualitative level (behavioral) and on the quantitative level (response time, throughput, loss rate, …). The development of formal description techniques and their integration in the design process require a better scalability of the verification techniques, and also a semantic coupling between formal approaches and semi-formal methods used in practice in the industry.

Topic 2. Communication Architectures and Protocols (CAP)

This topic deals with the design of advanced protocols, on one hand to handle multimedia information, multipoint services and cooperative aspects, and on the other hand to define new communication architectures that will provide guaranteed quality of service in general multi-domain, multi-network and multi-technologies environments. This topic also includes studies for characterizing the data traffic, anticipating its evolution and using measurement results to design architectures and protocols adapted to the constraints of the network and its actual traffic, in addition to the users requirements.

Topic 3. Components and Services of Co-operation (CSC)

With this topic we study methods and techniques for designing and developing distributed software architectures, both dynamic and adaptative, as well as defining their associated coordination protocols. The application field is the support of distributed cooperative activities. Projects mainly concern the development of coordination software tools and of group coordination services. Different technologies are used to validate and implement the services and to integrate the different components, among which Web services, CORBA standards, CCM components technologies, EJB and peer-to-peer architectures.

In order to complement and evaluate these scientific topics on more specific aims, three internal projects, of a limited duration, have been defined:

1. DISTRIBUTED COOPERATIVE ENGINEERING

This project aims at developing the PLATINE cooperative environment, which integrates multimedia cooperative components allowing audio and video dialogues. This environment supports collaborative work and also allows to share documents and dedicated software, first developed for single-user. PLATINE is used in the context of different French and European projects and is currently being transferred to industry via the CNRS.

2. COOPERATIVE MULTIMEDIA EXPERIMENT PLATFORM

This project aims at implementing an experimental cooperative multimedia platform within the laboratory, meant to support research projects. It uses RENATER 3, which also gives access to the GEANT European research network. As far as hardware is concerned, it is made of Unix and PC workstations, but also integrates active and passive measuring probes, machines for analyzing related traffic traces, and a wireless experimentation platform (WIFI).

3. REAL-TIME DISTRIBUTED SYSTEMS AND CONTROL/COMMAND

This new project falls in the general context of implementing applications for the control/command of physical processes on computers connected to a network. It comprises studies on the QoS and analysis of the influence of QoS (at the executive and network levels) on the performances of control/command applications.

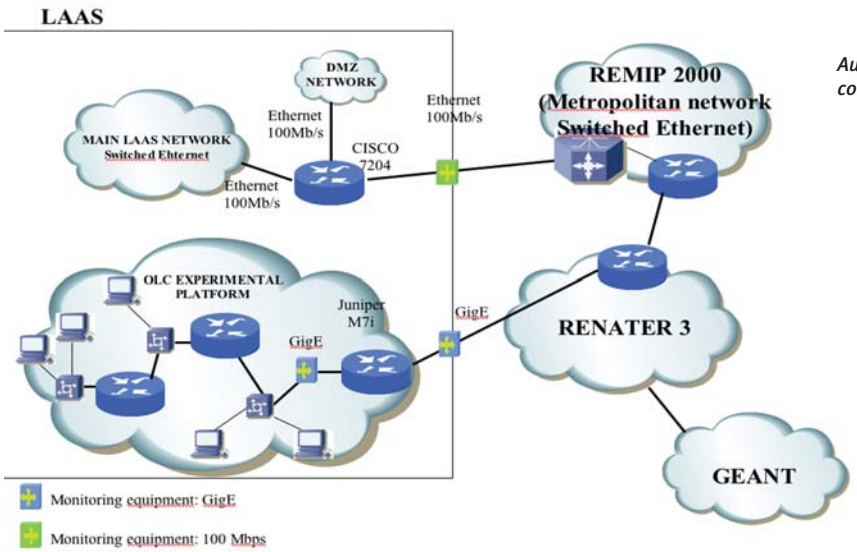
Contractual projects

The group has conducted and still conducts an important activity for transferring and valorizing its results, together with both other public laboratories and industrial companies of the sector, such as Alcatel Space, Airbus, EADS, France Telecom R&D, Thales, 6Wind, Realix and Silogic.

The group has contributed and still contributes to the EC IST program, as participant or coordinator: of several contracts in the network and multimedia field (new transport layer for the Internet, transparent satellite access to the IP protocol, new QoS architectures); of the design of cooperative architectures and support environments for cooperative distributed engineering; and of the implementation of advanced pedagogic theories and support systems in the context of augmented reality and virtual reality with mobile users.

Finally, the group took part and still takes part in several projects in the context of national research networks, RNRT and RNTL, in the field of convergence of fixed and mobile networks, group communications, metrology for the Internet and development environment for modeling and validating real-time applications.

Collaborative Engineering with PLATINE



Autonomous platform for networking and collaborative experiments

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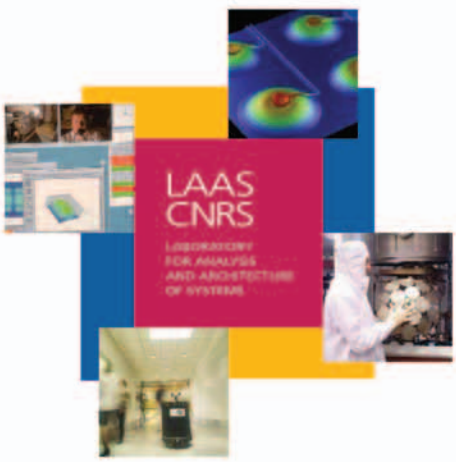

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