ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

ASTRONOMY, ASTROPHYSICS AND COSMOLOGY

Understanding the content and evolution of the Universe.

The research of the University of Bologna covers a wide range of topics:

- Stellar population studies based on space imaging in the UV (HST, GALEX, AstroSat), optical (HST), and infrared (Spitzer), and on ground-based spectroscopy
- Physics and evolution of galaxies and AGNs based on space data across the entire electromagnetic spectrum
- Cosmology and dark matter studies with gravitational lensing, galaxy clusters, large scale structure and neutral hydrogen
- End-to-end simulations of imaging and spectroscopic data
- Statistical analysis of large datasets
- Numerical simulations for astrophysics and cosmology

HIGHLIGHTS

The University of Bologna participates in the following space missions and projects: ESA Euclid cosmological mission to address the key questions of dark energy and modified gravity (top-level responsibilities in management and science); AMS (Antimatter Magnetic Spectrometer): the study of antimatter and dark matter through a cosmic ray detector on the ISS (International Space Station); eROSITA, on-board of the "Spectrum-Roentgen-Gamma" satellite to survey the whole sky in the X-rays; ESA Athena X-ray space mission to address the cosmic evolution of black holes and large massive structures; Indian Space Telescope AstroSat; Space VLBI RadioAstron Project; ERC Advance Grant "COSMIC-LAB" on stellar physics and evolution; ERC Advance Grant "GLENCO" on gravitational lensing; ERC Starting Grant "DRANOEL" on radio emission in galaxy clusters; ERC Starting Grant "MAGCOW" on extragalactic magnetic fields; FP7 CIG "eEASy" on active galaxies "FP7 CIG "INACMa" on early life and palaeoenvironmental reconstructions; National funded projects: Euclid mission, MIUR-SIR "SIMCODE" on cosmological simulations, MIUR-FARE "SMS" on magnetic fields in galaxy clusters; HST (Hubble Space Telescope) Large Project on stellar populations; ENGRAVE & GRAWITA projects for the identification and study of the electromagnetic counterparts of gravitational waves PAPSSN (Pan-African Planetary and Space Science Network).

Infrastructures and collaborations

Open Physics Hub: multi-purpose laboratory for the development of new generation sensors and detectors, high-speed computing and data visualization.

Different research groups have established an extensive **network of collaborations** with several universities, agencies, institutions and research centers at national and international level, such as: ASI (Italian Space Agency), INAF (National Institute for Astrophysics), INFN (National Institute for Nuclear Physics), ESA, NASA, JPL (Jet Propulsion Laboratory – NASA), DOE (U.S. Department of Energy), ESO (European Southern Observatory), MPE (Max Planck Institute for Extraterrestrial Physics).

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EARTH OBSERVATION APPLICATIONS

Applications of optical and radar Remote Sensing, and other EO data, exploited for a broad spectrum of topics.

The University of Bologna has been involved in several studies concerning Earth Observation applications covering the areas of Agriculture, Geology, Hydrology, Land Cover and Use, Mapping and Risk Management.

The research of the University of Bologna covers a wide range of topics:

- Risk management for disasters (earthquakes, floods, fires, landslides, etc.), quick mapping in emergency phases, crowdmapping solutions
- Land Use/Land Cover changes detection. Characterization and interpretation of landscapes and evolutionary trajectories; fragmentation analysis; environmental monitoring, GIS Multi-Criteria Spatial Decision Support Systems
- Precision agriculture and farming, support to rural development policies. Optical and microwave remote sensing for soil moisture measurement
- Water resources management, water quality, glaciology
- Mapping of impervious, urban sprawl monitoring, EO/GIS for urban planning. Thermal remote sensing, Urban Heat Island
- Coastal zone protection and management, subsidence monitoring
- Archaeological applications of Remote Sensing
- EO for extreme environments and polar regions
- Climate change. Arid environments and desertification
- EO for humanitarian crisis management
- Spectroscopic measurements of the atmosphere from space, modeling of the atmospheric measurement chain
- Sea level from altimetry, surface winds from scatterometers, sea surface temperature and ocean color from radiometers, marine pollution from Synthetic Aperture Radar
- Use of ESA Sentinel-1, S-2 imagery for the assessment of forest disturbance
- Reflectance/albedo data for the assessment of vegetation productivity. Assessment of vegetation biochemical contents by hyperspectral imagery
- Aerial and terrestrial LiDAR and photogrammetry for 3D city models, DTM/DSM generation for environmental monitoring, geomorphology, landslides, etc.
- Processing of historical aerial images
- Applications in the framework of Copernicus program

HIGHLIGHTS

The University of Bologna participates in the **Copernicus Academy**.

Over the years the University of Bologna has been involved in national and international **projects** funded by ESA and the EU, among them: **Atlantos**, **Subcoast**, **EnergyCity**, **EblaChora**, **Spartacus**.

Different research groups have established an **extensive network of collaborations** with several institutions and research centers at national and international level, such as: ASI (Italian Space Agency), ESA, NEREUS (Network of European Regions Using Space Technologies), CNR (National Research Council – Italy), INGV (National Institute for Geophysics and Volcanology), INAF (National Institute for Astrophysics), PNRA (National Program for Antarctic Research).

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EARTH OBSERVATION
TECHNOLOGIES

Application and development of innovative data acquisition, modelling, processing solutions for EO data, with the aim to improve the quality and the type of the products

The University of Bologna is active in research activities on Earth Observation technologies with a particular focus on methods, algorithms, data fusion, numerical modelling and simulations.

The research of the University of Bologna covers a wide range of topics:

- Algorithms and processes for radiometric pre-processing of airborne and satellite images
- Radiometric calibration and validation by ground measurements
- Algorithms and processes for geometric processing of UAV, airborne and satellite images, GNSS integration
- Development of forward and inverse methods in the Remote Sensing of the atmosphere
- Numerical modelling and simulations, adaptive sampling, design of experiments, statistical methods
- Development and validation of new algorithms and indexes for change detection and monitoring from EO data
- Classification techniques for EO images
- Development and validation of novel algorithms for the assimilation of solar-induced chlorophyll fluorescence (ESA-FLEX Earth Observation Mission), Cal-Val activities towards ESA-Sentinel-3 data assimilation
- Altimetry data generation from satellite missions
- Processing of Aerial and Terrestrial LiDAR data, feature extraction algorithms
- Three-dimensional digital surface modeling by UAV, aerial and satellite imagery by advanced image matching procedures
- Data fusion of multisource datasets (multispectral/thermal/radar), integration of geospatial data in multi-scale GIS solutions
- Methods for data quality evaluation and accuracy assessment
- Applications in the framework of Copernicus program

HIGHLIGHTS

Over the years the University of Bologna has been involved in national and international **projects and experiments** funded by ESA and the EU, among them: **FLEXDVM**, **Sen3Exp**, **Photosynthesis**, **FLEX-BRIDGE**, **FLEX L1B to L2**.

Different research groups have established an extensive network of collaborations with several institutions and research centers at national and international level, such as: ASI (Italian Space Agency), ESA, CNR (National Research Council – Italy), PNRA (National Program for Antarctic Research), INAF (National Institute for Astrophysics), INGV (National Institute for Geophysics and Volcanology).

EGNSS SERVICES AND APPLICATIONS

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EGNSS data is nowadays a critical technology in a very wide spectrum of applications including, but not limited to, navigation, monitoring ground movement and the atmosphere.

The University of Bologna has great expertise on EGNSS data processing both for precise positioning (using several scientific software packages such as Bernese, Gamit, Gipsy-Oasis) and for navigation. This skill is fundamental to provide services in different contests. During the years, this technology has been applied on several research areas: the University of Bologna has gained a significant expertise covering a wide spectrum of applications.

The research of the University of Bologna covers a wide range of topics:
- Space: development of real-time accurate orbit determination techniques based on GNSS measurements
- Geodesy: studies related on definition and maintenance of Global and Regional Terrestrial Reference Systems (and frames)
- Geodynamics: study of the evolution of the plate tectonic motion trough a very dense network of GNSS permanent stations
- Geology: monitoring of landslides, subsidence, using both geodetic or low cost GNSS receivers
- Structural engineering: monitoring of structures (bridges, dams, towers) using GNSS permanent stations
- Navigation: development of technologies for accurate navigation systems integrated with other sensors for Safety of Life, mobile mapping or precision farming
- Atmosphere: mapping of Tropospheric and Ionospheric delay for meteorology, climate change and deep space navigation applications
- Antarctica: crustal deformation and Glaciological Studies

HIGHLIGHTS

GNSS data processing using scientific software packages in classical differenced approach and in Precise Point Positioning for both high accurate positioning and atmospheric parameter estimation (TEC, Tropospheric delay).

Simulation and data analysis center for satellites orbit estimation.

Infrastructures: The University of Bologna handles a network of 10 GNSS permanent stations mostly located in the Pianura Padana and disposes of a software package to deliver correction for Real Time applications.
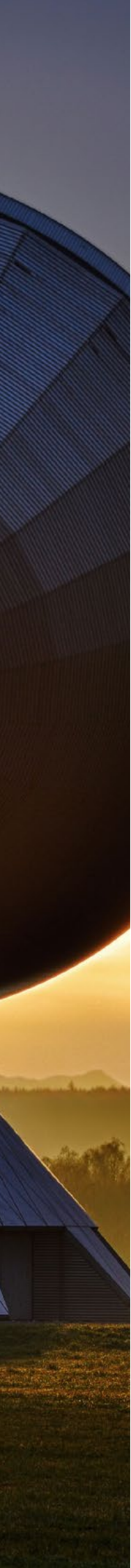
Different research groups have established an **extensive network of collaborations** with several institutions and research centers at national and international level, such as: ASI (Italian Space Agency); PNRA (National Program for Antarctic Research); EUREF (Reference Frame Sub-Commission for Europe); NEREUS (Network of European Regions Using Space Technologies); NASA.

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SPACE AND COMMUNICATION SYSTEMS AND NETWORKS

The communication system is a key and critical element for space applications, as satellites are built to gather data through sensors or to serve as relay for users in a network.

The University of Bologna is active in research activities on space communication regarding the design and performance assessment of SatCom systems and architectures, digital mo-demodulation and coding schemes, multiple access and network protocols, signal processing for GNSS, UWB signal design for on-board objects localization and tracking.

The research of the University of Bologna covers: Shannon Information Theory and Capacity Assessment for Space Communication; Error Correcting Coding; Post-quantum cryptography; Uncoordinated multiple access based on codes on graphs; On board Ultrawideband (UWB) localization systems and multistatic Radar for objects tagging and tracking with centimeter accuracy; Advanced Signal Processing and Spread Spectrum techniques for GNSS; Bandwidth/Power Efficient Digital Modulation techniques for Communication; Synchronization and Channel Estimation; Spectrum Sensing and Cognitive Radio; Simulation of Communication Systems; Interference management (Suppression, Cancellation, Multiuser Detection), diversity techniques (multiple antenna communications, beamforming, cooperative diversity); Satellite Communication systems and architectures for broadband and broadcast services; Satellite communication networks for 5G; Satellite networks based on micro-mini satellites; InterPlanetary Internet (IPN) Protocols and Architectures; M2M Communications for SatCom; Mobile Edge Computing and Caching for SatCom; Wireless Power Transfer RF and Antenna technologies; Software/firmware for FPGA/DSP implementation of space communication transceivers.

HIGHLIGHTS

The University of Bologna participates in:

- The University of Bologna coordinates the H2020 project "DYNASAT - Dynamic Spectrum Sharing and Bandwidth-Efficient Techniques for High-Throughput MIMO Satellite Systems"
- DVB SatCom standardization process for broadband and broadcast future system (ESA projects)
- 3GPP SatCom component development through the SatCom working group of Networld2020
- Multiple ESA initiatives toward development of future SatCom technologies, including several ESA-funded projects addressing both near-Earth and deep-space communications"
- CCSDS (Consultative Committee for Space Data Systems) definition of international standards for Synchronization and Channel Coding, designed for space communications links primarily between spacecraft and ground elements (with the main international space agencies)

Different research groups have established an **extensive network of collaborations** with several institutions and research centers at national and international level, such as: ASI (Italian Space Agency), DLR (German Aerospace Center), ESA, JPL (Jet Propulsion Laboratory), NASA.

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SPACE COMPONENTS
AND
SYSTEMS

Space Components and Systems for reliable space probes.

The University of Bologna is deeply involved in research activities dealing with space components such as microwave and RF circuits, high efficiency power supplies, high-speed ADC systems. Moreover, there is a wide expertise in space system engineering, including the design, assembly, and in-orbit operations of small satellites.

The research of the University of Bologna covers a wide range of topics:

- Design, characterization and modeling of Microwave Monolithic Integrated Circuits (MMIC) and Hybrid Circuits in GaAs, GaN and Silicon technologies for radar, telecom, remote sensing and TT&C applications
- Characterization and behavioral non-linear dynamic modelling of high-speed, broad-band A/D acquisition channels for RF receiver architectures
- Design of switching power supplies exploiting power devices in GaN on Si technology and FPGA based control strategies
- Design and development of accurate models and innovative testing and fault tolerance techniques for the most likely faults affecting digital circuits implemented in scaled (nanometer) Silicon technologies, emergent (non-Silicon) technologies, and photovoltaic systems
- Design and development of COTS-based GNSS receivers for small satellites navigation applications
- Spacecraft Attitude Determination and Control System (ADCS) studies for micro-/nano-satellites, including numerical and experimental test platforms
- Spacecraft Subsystems & Technologies: design, development and testing
- Spacecraft Platforms & Missions design
- Design and Assembly of Spacecraft Mission Control Centers and Ground Antenna Tracking Systems

HIGHLIGHTS

Participation in space missions and experiments of the University of Bologna:

- 2012: Launch of **ALMASat-1**, the first microsatellite of the University of Bologna
- 2018: Launch of **ESEO** (European Student Earth Orbiter) and ESA Educational spacecraft with an University of Bologna's on-board payload dedicated to autonomous GPS-based orbit determination
- 2020-21: Participation in the Phase A study of the **INFINITY** project for amateur astronomy observations
- 2021-2022 (TBC): Launch of **uHETSat** and **STRIVING** satellite missions, where UNIBO developed the Ground Mission Control Center

Infrastructures:

- **Alma Mater Ground Station**: a Spacecraft Mission Control Center and Antenna Tracking System fully operational for Low-Earth Orbiting satellites since 2004
- **Microsatellite and Space Microsystems Laboratory** with cutting-edge research facilities, including a Spacecraft Attitude Determination and Control System test-bed

Different research groups have established an **extensive network of collaborations** with primary European companies operating in the space sector as well as with several institutions, universities and research centers such as: ASI (Italian Space Agency), ESA, NASA.

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SPACE EXPLORATION

Exploring space to advance our knowledge and innovate technology.

The University of Bologna is involved in several space exploration projects.

- Space mission remote sensing/imaging, astrodynamics, orbit determination, deep space navigation, radio-tracking
- Applications of thermal and cold plasma in spaceflights
- Portable multiplex biosensors and devices for the in-flight monitoring of biomarkers in astronaut physiological changes and strength recovery. Effects of space conditions on cells
- Ageing, immunology, immunosenescence, microRNA and epigenetic changes in space, muscle performance in zero gravity, calcification, space bioreactor
- Hibernation, thermoregulation, sleep regulation, radiation resistance, physiology
- High-resolution molecular spectroscopy, quantum chemical calculations, prebiotic and complex organic molecules
- Microbial life in extreme environments. Lab-on-chip devices for detecting biomarkers of extant or extinct extraterrestrial life

HIGHLIGHTS

The University of Bologna participates in major projects and experiments such as:

- NASA/ESA/ASI Cassini-Huygens, ESA SMART-1, ESA BepiColombo, ESA ExoMars, NASA JUNO, ESA JUICE missions, NASA Europa Clipper, ESA Hera, ASI LICIACube, ASI ArgoMoon (radio science experiments)
- ESA Topical Team Hibernation
- Portable bio analyzer (IN SITU project) employed by the ESA astronaut P. Nespoli in his VITA mission onboard the ISS
- SPARE (Space Radiation Shielding) project with ASI and INFN
- Europlanet 2024 RI
- NASA mm/submm heterodyne sensor for outer solar system exploration
- BIOSIGN-MICROFOSSILS experiment onboard the ISS
- Exploration of the Danakil Depression as planetary analogue
- SARCOLAB-3 project with DLR, ESA, NASA

Facilities and infrastructures: Laboratory for physiology of the autonomic nervous system; Laboratory for Astrobiology and Geomicrobiology; Laboratory for clinical & functional evaluation; Tesla Plasma laboratory for non-thermal plasma; Langmuir BioPlasma Bacteria laboratory; Open Physics Hub laboratory for sensors and high-speed computing; Laboratory for high-resolution molecular spectroscopy; Laboratory of Analytical and Bioanalytical Chemistry; Laboratory for motion analysis in zero gravity conditions. The University is also part of STAR the Interuniversity Center for Astrochemistry Radio Science and **Planetary Exploration Lab**.

Extensive collaborations are present with primary European companies and as well as with several universities, agencies and research centers such as: ASI, INAF, INFN, INGV, ESA, NASA, DLR, TIFPA, EANA, ESSC, ALMA Regional Center, MPE, CNRS.

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SPACE PROPULSION, POWER AND THERMAL SYSTEM

Space Propulsion, Power and Thermal Systems are essential tools to enable space exploration, in particular at large distances from the Sun and in extreme environments.

The University of Bologna is deeply involved in technological research activities such as chemical propulsion, electric propulsion, plasma modeling and spacecraft electrical power systems.
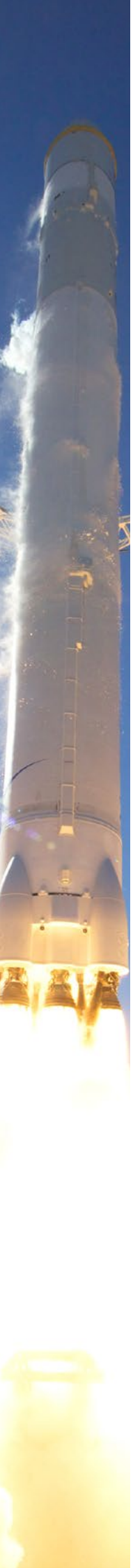
The research of the University of Bologna covers a wide range of topics:

- Magneto Hydro Dynamics electric power generation
- Space electric propulsion (Magneto Plasma Dynamic – MPD, and Hall effect thruster)
- MHD interaction in hypersonic regimes, with a focus on the re-entering of space vehicles in the atmosphere, as a technique to mitigate thermal fluxes and to control the vehicle trajectory
- Dielectric barrier discharges (DBD) capable of producing a cold plasma volume in air at atmospheric pressure. Basic analysis of the discharge, including modelling and plasma diagnostics, as well as the development of specific technological applications
- MEMS-based Gold-Gas Micropropulsion (molecular nitrogen)
- MEMS-based monopropellant Warm-Gas Micropropulsion (high-text peroxide)
- Solid Rockets Propellant packing analysis, using analytic and numerical approaches, both for close and loose packing. Capability to relate packing parameters with the propellant viscosity
- Solid rocket engines internal ballistic modeling: 3D burning surface regression models, fluid-dynamic approach for the internal parameters, and modeling both for solid/hybrid rocket engines
- Spacecraft Power Systems modeling, analysis and simulation

HIGHLIGHTS

The University of Bologna's participation in space missions and experiments:

- Development of MEMS based monopropellant high-test peroxide μ-thrusters
- Investigation on the physics and microfluidics of the decomposition of H2O2 in MEMS μ-thrusters (USAF AFOSR)
- Research projects aimed at using the MHD interaction in the re-entry phase of a spacecraft (PS-just/HPF/MHD-AFC)
- Research projects aimed at the development and implementation of aerothermodynamic codes
- Research on DBD actuators for flow control

Infrastructures:

- Micropropulsion testing equipment within the **Microsatellite and Space Microsystem Labs**: microscope equipped with high speed camera, thrust balance, high-test peroxide distillation facility, mass flow meter and controller plus various fluidic equipment
- **LIMP** – *Magnetofluiddynamic Engineering and Plasma Lab*

Different research groups have established an **extensive network of collaborations** with primary European companies operating in the space sector as well as several institutions and research centers at national and international level, such as: ASI (Italian Space Agency), ESA, AFOSR (Air Force Office of Scientific Research).

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SPACE ROBOTICS, AUTOMATION AND CONTROL SYSTEMS

Space Robotics, Automation and Control Systems are an interdisciplinary research field which mixes typical expertise from ICT and industrial engineering departments.

The University of Bologna has been involved in space robotics research for several decades. The activities range from dynamic and kinematic modeling of multibody systems, to their active control.

The research of the University of Bologna covers a wide range of topics:

- Analysis of robotic systems and manipulators
- Robotic hands and arms
- Telemanipulation
- Design and control of robotic systems for space exploration (rovers, arms for sampling and picking, end-effectors, tools)
- Design and control of robotic systems for satellite service and maintenance (robotic arms and grippers)
- Dynamic modeling of multibody systems with rigid and compliant components
- Innovative actuators, motion measurement and analysis
- Elastodynamic modelling of mechanical system
- Experimental analysis of vibration
- Vibration qualification testing

HIGHLIGHTS

The University of Bologna participates in several **projects and experiments** funded at EU and national level: **DEXMART**, **TRIDENT**, **AIROBOTS**, **SHERPA**, **WIRES**, **AIRBORNE**, **MARIS**.

The **PhD program**, currently in progress, deals with the mission synthesis for tailored vibration qualification tests: "Advanced Mission Synthesis Algorithms for Vibration-based Accelerated Life Testing".

Infrastructures:

- Electrodynamic Shaker Dongling ES-2-150 with Slip Table Dongling GT400M-1; closed-loop control S/W LMS SCADAS III SC302VB; Differential Laser Vibrometer Polytec HSV 2002 and High Speed Rotational Laser Vibrometer Polytec RLV 5500
- Laboratory on Automation and Robotics (LAR), Center for Complex Automated Systems (CASY): laboratories equipped with many robotic systems (mobile, collaborative, industrial), fast prototyping facilities, vision systems (e.g. Vicon, Optitrack, etc.), CNC machines, CAD tools, flying rooms

Different research groups have established an **extensive network of collaborations** with institutions and research centers at national and international level, such as: ASI (Italian Space Agency), IIT (the Italian Institute of Technology); ISME (Italian Center on Integrated System for Marine Environment), ESA.

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SPACE SOFTWARE
AND DATA SYSTEMS

A satellite in space produces a fountain of information. Data Systems oversees the technologies involved in spacecraft onboard data handling (OBDH) system.

The University of Bologna is involved in research activity about Space Software and Data Systems related to telecommand protocols, image analysis, data fusion, and firmware design.

The research of the University of Bologna covers a wide range of topics:

- Software for telemetry protocols, erasure resilient codes, automatic repeat request
- Software/firmware for FPGA/DSP implementation of space communication transceivers
- Software for InterPlanetary Internet Protocols
- Software for Mobile Edge Computing and Caching in Satellite Commmunications
- Image sequence analysis, image registration, videogrammetry
- 2D/3D Planet surface analysis, measurements and mosaicing 3D rendering of simulated surfaces
- Multi-sensor remote sensing
- Data fusion of IMU and visual information from 3D image analysis
- Mobile SLAM algorithms for 3D scene reconstruction
- Software for autonomous and image-based attitude determination of LEO satellites

HIGHLIGHTS

The University of Bologna participates in:

- the creation of the *Solar System Internet Delay/Disruption Tolerant Networking* (**DTN**) service on the International Space Station (NASA).
- **CCSDS** (*Consultative Committee for Space Data Systems*) definition of international standards for software systems aimed at packet erasure correction in space communication protocols (in collaboration with the main international space agencies).

Different research groups have established an **extensive network of collaborations** with several institutions and research centers at national and international level, such as: ASI (Italian Space Agency), DLR (German Aerospace Center), ESA, JPL (Jet Propulsion Laboratory), NASA.

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SPACE STRUCTURES
AND
MATERIALS

Cutting-edge research on space structures and materials is an essential tool to enable space exploration, in particular requiring lightweight and improved thermal properties.

The University of Bologna is involved in research activities dealing with polymer related materials, from functional macromolecules to structural materials such as (nano)-composites and recycling thereof. Furthermore, our research addresses the design of fully optimized structures in order to enable the aerospace products of tomorrow, meeting the increasing performance needs.

The research of the University of Bologna covers a wide range of topics:

- New advanced graphene-based polymer matrices to be used for carbon fiber composites production
- Composites with outstanding properties, such as improved thermal conductivity and toughness
- Novel nanofibrous additives for structural and functional modification of composite structures (i.e. for damping, delamination and toughness improvement)
- Structural analysis of metallic and composite structures
  - Delamination growth analytical and numerical models
  - Experimental test of crash behavior in carbon fiber reinforced plastic (CFRP) components
  - Numerical modeling of progressive damage in CFRP structures
  - Thermo-mechanical, dynamic and vibration analysis of space structures
- Laser Shock Peening (LSP)
  - LSP treatment of aluminum specimens to increase their structural performance
  - Residual stress measurement and prediction through numerical models
- Additive Manufacturing
  - Additive manufacturing technologies for rapid tooling
  - Design of optimized components fabricated through AM technologies

HIGHLIGHTS

Infrastructures:

- **Composite Materials Laboratory** with equipment and expertise to assembly composite structural components using vacuum bagging technology
- **The Metallography Laboratory** for microstructural analysis is equipped with optical microscope, magnification up to 1000x, bright field and polarized light using LUCIA image analysis programme
- **Mechanical Testing Laboratory** allowing tension-compression fatigue tests; 3 point bending tests; torsion fatigue tests; hardness measurements; surface roughness measurements; Friction Stir Welding testing; rotating bending testing machine; Non-destructive testing

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TOOLS FOR OPTIMAL EXPLOITATION OF SPACE DATA

Efficient algorithms to decipher the complexity of space data.

The University of Bologna is deeply involved in several interdisciplinary projects aimed at collecting, modelling and processing space data.

- Geodetic data (GNSS, SLR, SAR) for crustal deformation studies. Space and terrestrial gravity data. Modelling short- and long-period signals in space geodetic coordinate time series. Sea-level variations. Physical parameters of the ITRS
- Algorithms for space data analysis and modeling to monitor ocean changes. Copernicus Sentinel marine satellite data fusion techniques to reconstruct the ocean state and forecast the ocean weather
- Remote sensing measurements of the atmosphere. Trends of gases regulated by international agreements. Retrieval algorithms for inversion of atmospheric spectral radiances. Diagnostic tools and simulations for studies of new space mission concepts
- Measurements of planet surfaces. Data fusion with visual information from 3D image analysis. Image-based satellite's attitude determination. 2D/3D mosaicing of surface of planets. Multi-sensor remote sensing
- Big Data management and analysis tools for temporal and geographic information retrieval, data integration, predictive models
- Integration of spectroscopic and kinetic databases for Astrochemistry. Quantum-chemical calculations of reactive potential energy surfaces, thermochemistry and kinetics

HIGHLIGHTS

The University of Bologna participates in the Copernicus Academy; in the development of models and data assimilation systems for short-term ocean predictions and climate reconstructions using earth satellite data; in a NASA project for a mm/submm heterodyne sensor for spectroscopy and imaging of cold planetary objects in the outer solar system; in FORUM mission within the ESA Earth Explorer 9 program; in EU-funded projects on sea-level variations in the Mediterranean.

Facilities and infrastructures: Computing facility for the image analysis of planet surfaces; Computing facility for geodetic data analysis; Network of permanent GPS stations for geodesy; Computing facility for the analysis of ocean and marine data; Computing facility for geographic Big Data management; Facility for quantum mechanical calculations (molecules); an Open Physics Hub laboratory for sensors and high-speed computing.

Extensive collaborations are present with primary European companies operating in the space sector and Big Data analysis as well as several institutions and research centers at national and international level, such as: ASI, CNR, ESA, NASA, INAF, INGV, MPE, LAREG, BKG, CMCC; STAR Interuniversity Center for Astrochemistry.