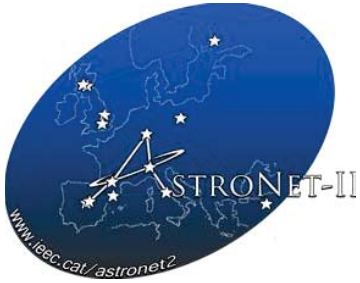

AstroNet-II

The Astrodynamics Network

part of the Marie-Curie Research Training Network on Astrodynamics

Research projects Booklet

AstroNet-II training programme centres on projects for Early Stage Researchers (ESRs) and Experienced Researchers (ERs) that cross the traditional boundaries between mathematics, engineering and industry, ensuring that they obtain an interdisciplinary and multi-sectorial overview of the field. This is supported by an extensive programme of Schools, Workshops, Tutorials and Internships, and by a close collaboration between academia and space companies.

This booklet aims to illustrate the single projects of the AstroNet-II researchers to provide a complete picture of "who is doing what" in the Net.

Politecnico di Milano (PoliMi)

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Project Title:

Project Description:

GMV Aerospace and Defence SA (GMV)

Pedro Llanos de la Concha
pjllanos@gmv.com

Project Title:

Novel techniques for missions to Asteroids and the Martian Moons.

Project Description:

This research project will be devoted to investigate novel techniques for proximity operations to a) single and binary asteroids and b) the moons of Mars, Phobos and Deimos. This research will be dedicated to investigate novel guidance, navigation and control techniques during the different phases of the mission: descend and landing, orbit maintenance and station-keeping using different propulsion systems. We will investigate the stability of orbits around selected target asteroids in support to the Marco Polo R mission, which will return an asteroid sample in the next decade, and the stability of orbits around Phobos and Deimos. Finally, this project will deal with the design and optimization of the transfer trajectory to these bodies.

AstroNet-II Partners

Institut d'Estudis Espacials de Catalunya (IEEC). Barcelona, Spain.
Scientist-in-charge: Prof. G. Gómez (*Network Coordinator*) and Prof. J.J. Masdemont

Clyde Space Limited (Clyde Space). Glasgow, United Kingdom.
Scientist-in-charge: Ing. S. Greenland

Deimos Space SL (Deimos). Madrid, Spain.
Scientist-in-charge: Ing. M. Sánchez, Ing. J.L. Cano, Dr. L.F. Peñín

GMV Aerospace and Defence SA (GMV). Madrid, Spain.
Scientist-in-charge: Ing. M. Graziano, Ing. J. Gil, Ing. T. Prieto

Middle East Technical University (METU). Ankara, Turkey.
Scientist-in-charge: Prof. O. Tekinalp, Prof. K. Ozgoren, Dr. A.T. Kutay, Dr. I. Yavrucuk

Politecnico di Milano (PoliMi). Milano, Italy.
Scientist-in-charge: Prof. F. Bernelli

University of Strathclyde (Strathclyde). Glasgow, United Kingdom.
Scientist-in-charge: Dr. J. Biggs, Prof. C. McInnes, Dr M. Macdonald, Dr. M. Vasile

University of Surrey (Surrey). Guildford, United Kingdom.
Scientist-in-charge: Dr. P. Palmer, Prof. M. Roberts

Turun Yliopisto (Turun). Turku, Finland
Scientist-in-charge: Dr. S. Mikkola, Dr. T. Korhonen, Prof. E. Valtonene

Universita degli Studi di Roma Tor Vergata (UTV). Roma, Italy.
Scientist-in-charge: Prof. A. Celletti, Dr. U. Locatelli

Uniwersytet Zielonogorski (Zielona Gora). Zielona Gora, Poland.
Scientist-in-charge: Dr. K. Goździewski, Prof. A.J. Maciejewski, Prof. M. Przybylska

Associated Partners

Astrium Limited Satellites (Astrium). Stevenage, United Kingdom.
Scientist-in-charge: Dr. S. Kemble, Ing. A. Povoleri, Ing. N. Croisard

European Space Agency / ESOC (ESA/ESOC). Darmstadt, Germany.
Scientist-in-charge: Ing. J. Schoenmaekers

Thales-Alenia-Space (TAS). Toulouse, France.
Scientist-in-charge: Dr. T. Dargent, Dr. V. Martinot, Dr. J. Fontdecaba

Deimos Space SL (Deimos)

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Project Title:

Project Description:

Clyde Space Limited
(Clyde Space)

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Project Title:

Project Description:

Early Stage Researchers (ESR)

- **IEEC**
  ESR-1: Zubin P. Olikara
  ESR-2: Fabrizio Paita
- **METU**
  ESR1: --
- **Strathclyde**
  ESR-1: Mattia Zamaro
  ESR-2: Albert Caubet
- **Surrey**
  ESR-1: Elisabetta Iorfida
  ESR-2: Andrea Turconi
- **TURKU**
  ESR1: Claudiu-Lucian Prioroc
- **UTV**
  ESR-1: Marta Ceccaroni
  ESR-2: Rocio I. Paez
- **Zielona Gora**
  ESR-1: Leon C. Simpson

Experienced Researchers (ER)

- **Clyde Space Limited**

ER1: --

- **Deimos Space SL**

ER1: --

- **GMV Aerospace and Defense SA**

ER1: Pedro Llanos de la Concha

- **Politecnico di Milano**

ER1: --

Experienced Researchers

Uniwersytet Zielonogorski (Zielona Gora)

Leon C. Simpson
leonsimpson@fmail.co.uk

Project Title:

Coupled dynamics of two extended bodies.

Project Description:

The interaction of extended bodies under gravity is difficult to study, and to extract meaningful results it is useful to make certain approximations. A neat trick to model prolate bodies is to approximate them with a dumbbell: two spheres separated by a massless inflexible rod. Using complex masses and complex rod lengths, it is possible to model oblate bodies in this way also. This research concerns systems with either one or two dumbbells, with a focus on the presence of libration points, their stability, and any bifurcations that arise. Additionally, the question of integrability is addressed. It is our hope that this will result in a more complete understanding of such systems.

Early Stage Researchers

Institut d'Estudis Espacials de Catalunya (IEEC)

Zubin P. Olikara
zubin@maia.ub.es

Project Title:
Applications of invariant manifolds in astrodynamics.
Project Description:
We intend to explore spacecraft dynamics in the solar system using tools from invariant manifold theory. As a particular example, we can study motion in the vicinity of a binary asteroid by searching for solutions lying on invariant tori. In addition, we can design end-of-life trajectories for spacecraft via manifolds and potentially incorporate control such as solar sails.

Fabrizio Paita
fabrizio@maia.ub.es

Project Title:
Flocking Behaviour in Satellites Formation Flying.
Project Description:
My project takes place in the context of satellites formation flying and control. Specifically, for the moment being, I'm trying to adapt in the aforementioned context a particular "control acceleration", first introduced by F. Cucker and S. Smale in 2006 as a tool to study and

Rocio Isabel Paez
paez@mat.uniroma2.it

Project Title:
Perturbation Theory at work in AstroDynamics.
Project Description:
The project is based on the construction and the study of suitable Hamiltonian normal forms, in three different cases: a KAM torus, a lower dimensional torus of hyperbolic type, and one of elliptic type. The problems of increasing difficulty in Celestial Mechanics, where those normal forms will be applied, are i) the Sitnikov problem, ii) travels along the resonant manifolds in our Solar System and iii) the Cassini states for satellites, respectively.

University of Roma Tor Vergata (UTV)

Marta Ceccaroni
ceccaron@mat.uniroma2.it

Project Title:
Dissipative Effects on Attitude Dynamics.
Project Description:
My research project deals with the attitude dynamics of a spacecraft moving under the effects of several different dissipative effects. To this end both analytical and numerical approaches will be used, applying in particular perturbative and Kam theories, quasi-periodic approximations, and some numerical techniques such as Lyapunov exponents, frequency analysis and Greene's method. These procedures, indeed, provide an accurate description of the dynamics of the system. Moreover the project aims to extend such tools to more complex systems, with applications to the attitude dynamics, in order to obtain an accurate model of the rotational dynamics of the spacecraft, which will include dissipative effects. The theoretical analysis and numerical validation of periodic attractors, invariant tori and strange attractors will be carried on within the framework of each dissipative model, including the identification of the basins of attraction of the different resonances.

predict the dynamics of flocks of animals. The importance of the latter comes from the theoric results that support it, specifically from the exponentially fast convergence of the formation to a rigid body configuration, with the agents assuming all the same velocity and the relative distances between them being constant.

Middle East Technical University (METU)

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Project Title:

Project Description:

Turun Yliopisto (Turun)

Claudiu-Lucian Prioroc
claudiu-lucian.prioroc@utu.fi

Project Title:
Formation flying using low thrust propulsion.
Project Description:
A restricted 3-body problem will be derived that incorporates current low-thrust propulsion. A Lindstedt-Poincaré series expansion will then be used to derive equations for families of periodic orbits in the libration zones. Furthermore, numerical continuation methods will be used to find exact families of periodic orbits of fixed period. Suitable control algorithms will be developed to ensure that these formations remain rigid and stable.

Andrea Turconi
a.turconi@surrey.ac.uk

Project Title:
Efficient modelling of asteroids gravitational fields for autonomous approach Project.
Description:
Asteroids are the next destination for exploration and for the improvement of our knowledge of the Solar System. Tecniques to deal with their peculiar dynamical environment are important also for NEO hazard mitigation and for future exploitation such as asteroids mining. Typically, after arrival, the first month of every asteroid exploration mission is used for the modelling of the body gravitational potential using Earth-bound measurements. The aim of the research is to study how alternative models and techniques could enable onboard modelling of the asteroid and improve autonomous navigation in the vicinity of these bodies.

Strathclyde University (Strathclyde)

Mattia Zamaro
mattia.zamaro@strath.ac.uk

Project Title:
Low Thrust Non-Keplerian Orbits: The Mars-Phobos System.
Project Description:
Following ESA and NASA's current interest in developing future missions to the Mars moons, the research work of Mattia Zamaro aims to provide low-cost observation points and transfer trajectories for exploration through the development of a low-thrust four-body model for the Sun-Mars-Phobos system, which will be used to identify unique positions for manned flights to Mars for undertaking real-time robotic investigations of Phobos and Mars while reducing human exposure to radiation.

Albert Caubet
albert.caubet@strath.ac.uk

Project Title:
Optimal and feasible attitude motions for microspacecraft.
Project Description:
Small spacecraft – micro- and specially nano- spacecraft– have very limited resources to perform slew manoeuvres. The performance of the attitude control system is low, requiring the small processor to

calculate very optimal and low torque manoeuvres. Thus, there is a need for on-board control and planning algorithms to efficiently optimize a number of manoeuvre parameters, for a variety of attitude systems. My research aims to take in advantage advances such as geometric mechanics and control theory to develop, analyse and implement algorithms and mathematical models for attitude control on small spacecraft.

University of Surrey (Surrey)

Elisabetta Iorfida
e.iorfida@surrey.ac.uk

Project Title:
Modelling Multi-Objective Trajectory Optimisation.

Project Description:
The analysis and optimization of interplanetary space trajectories is one of the most challenging topic that astrodynamics scientists have to deal with. The aim of the trajectory design is not only to find a solution, but also to find the "best" solution in terms of a relevant parameter of the problem (such as the propellant consumption): the problem consists of looking for an optimal solution in the regions of the search space that satisfy the problem constraints.
The presented research focuses on multi-objective trajectories optimization. In particular there is an interest in investigating specific missions with defined "science return" objectives and optimizing them with a robust mathematical optimization method. The aim is to optimize not only a unique parameter, but a group of them, using a "pareto front" analysis. As the first part of the optimization process, the project is focused on mid-course correction analysis.