
 CENTRE NATIONAL D'ÉTUDES SPATIALES	Communautés de Compétence Technique CCT ORB – Mécanique Orbite CCT SCA – Systèmes de Commande & Automatique	 Communautés de Compétences Techniques http://cct.cnes.fr
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Seminar:

The 6-Degrees-of-Freedom dynamics of space debris

Tuesday, November 22nd 2016 (13:30 – 17:15)

Institut Aéronautique et Spatial (IAS) , Room A320

23 Avenue Edouard Belin, 31400 Toulouse, France

The translational motion of space debris is today extensively studied with 3-Degrees-of-Freedom orbit propagation models and observed using tracking data. But the knowledge of attitude motion is also needed for many applications related to space debris mitigation such as analyzing photometric data, designing Active Debris Removal systems and cataloguing high area-to-mass ratio debris. In addition, coupling between attitude and orbit motions may occur, for instance for specific spacecrafts' geometries. In such a case modelling the 6-Degrees-of-Freedom (6-DoF) dynamics of an uncontrolled space object is needed to predict the evolution of its disposal orbit.



In a first part, this seminar will deal with measurements and modelling of debris attitude motion. Examples for launchers upper stages and satellites, in LEO and GEO, will be given. In a second part, the seminar will focus on the atmospheric re-entry. Different strategies (controlled, uncontrolled, semi-controlled re-entry) will be presented and the issue of attitude controllability at low altitudes will be addressed.

If you are interested to attend this seminar, please register at:

<http://cct.cnes.fr/content/cct-orb-sca-6-degrees-freedom-dynamics-space-debris>

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For more information : clemence.lefevre@cnes.fr, christelle.pittet@cnes.fr

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Program :

13:15 – 13:30 **Welcome - Coffee**

13:30 – 14:00 **Debris Attitude Motion Measurements and Modelling**

Speaker: Stijn Lemmens (ESA/ESOC)

Duration: 30 min

Techniques for tracking the translational motion of space objects were already in place before the start of the space age and have led to catalogues of sufficient quality for collision avoidance, re-entry predictions, or general space traffic management. To this day, the attitude motion of space debris object, and generally defunct satellites or upper stages, are far less well known apart from individual studies or theoretical investigation into the effects of environmental torques. Precisely monitoring, understanding, and predicting attitude motion and the orbit-attitude coupling is of high interest for active removal or on-orbit servicing missions. In this talk, we will brief you on some of the first results coming out of a two year activity by ESA to merge radar, optical, and laser sensors to collaboratively measure and predict the attitude motion of large uncontrolled space objects in Low Earth Orbit. With case studies and comparison between similar objects, we will provide an overview with the relevant torques which shows predictable and explainable behavior, as well as a large set of still unexplained phenomena. Most of the examples will demonstrate the need for long term monitoring, in similar fashion as has been in place for decades for translational motion, if we truly wish to understand the behavior.

14:00 – 14:30 **Analysis of the coupled orbit and attitude dynamics of space debris in Geostationary Earth Orbit**



Speaker: Clémence Le Fèvre (CNES-CST)

Duration: 30 min

This presentation addresses the modelling of coupled orbit and attitude dynamics over the long term for space debris in Geostationary Earth Orbit. The Telecom-2B French telecommunication satellite is chosen as an example in order to investigate its orbital evolution observed over the years since its re-orbitation. First, the reflecting cross-sectional area is computed for all orientations of the spacecraft towards the Sun direction. Secondly, numerical propagations of the 6-Degrees-of-Freedom motion are performed using the Monte-Carlo method to take into account the uncertainties of the initial angular conditions. Different attitude regimes are highlighted including a stabilization of the spacecraft orientation towards the satellite-Sun direction. The probability to reach such a

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regime is estimated and the sensitivity to the thermo-optical properties of the spacecraft's facets is studied. Finally, the simulated orbital evolution is compared with observations using Two-Lines-Elements data.

14:30 – 15:00 **Study on the eddy current damping of the spin dynamics of space debris from the Ariane launcher upper stages**
 Speaker: Nicolas Petit (Mines Paris Tech)
 Duration: 30 min

TBD

15:00 – 15:20 **Coffee Break (20 min)**

15:20 – 15:50 **Analysis of GOCE reentry**
 Speaker: Stijn Lemmens (ESA/ESOC)
 Duration: 30 min



The re-entry of ESA's Gravity Field and Steady-State Ocean Circulation Explorer (GOCE) satellite in November 2013 was an exceptional one. The satellite remained fully operational until its last orbit, sending a final batch of housekeeping telemetry at an altitude of about 105km, including GPS and attitude data. This data set allows to decouple the orbital motion, normally the only observable the weeks prior to re-entry, from the attitude motion of the spacecraft. A clear attitude stabilization mode of the spacecraft was observed which was partially due to the controller being operation, but as well due to the aerodynamic shape of the object. As GOCE wasn't designed for this, nor was is anticipated, we will discuss the effects on re-entry predictions and the extension of lessons learned to similar objects.

15:50 – 16:20 **Compliance to Space Debris Mitigation rules drives LEO and constellations satellites design to insure a safe re-entry at end-of-life**
 Speaker: Brice Dellandrea (Thales Alenia Space)
 Duration: 30 min

Controlled, semi-controlled or non-controlled re-entry is implemented according to satellite dimension, propulsion and attitude control capabilities.

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16:20 – 16:50 Attitude control at very low altitudes: R&D study
Speaker: Sophie Narbonne (Airbus Defense & Space)
Duration: 30 min

TBD

16:50 – 17:15 Round Table
Duration: 25 min

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ACCESS MAP

From TOULOUSE BLAGNAC Airport

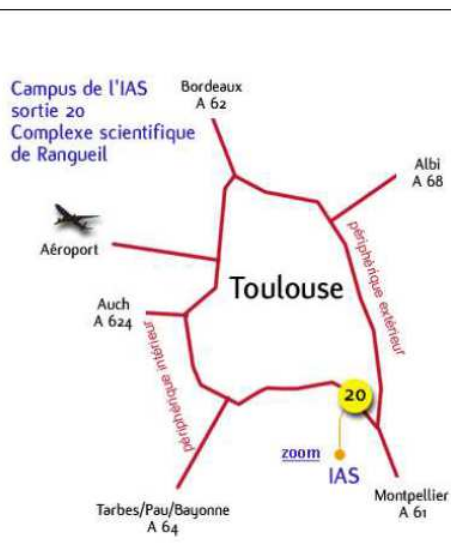
Bus shuttle to town center

Then subway line A direction Balma Gramont till Jean Jaures. Then take subway line B direction Ramonville Saint-Agne till Université Paul Sabatier. Then bus N°68 direction Lespinet Struxiano (ask for CNES & FIAS. bus stop)

From the SNCF Railway Station

Subway line A direction Basso Cambo till Jean Jaures. Then take subway line B direction Ramonville Saint-Agne till Université Paul Sabatier

Then bus N°68 direction Lespinet Struxiano (ask for CNES & FIAS. bus stop)



By Public Transportation:

Take subway line B direction Ramonville Saint-Agne till Université Paul Sabatier. Then bus N°68 direction Lespinet Struxiano (ask for CNES & FIAS. bus stop)

By Ring Roads:

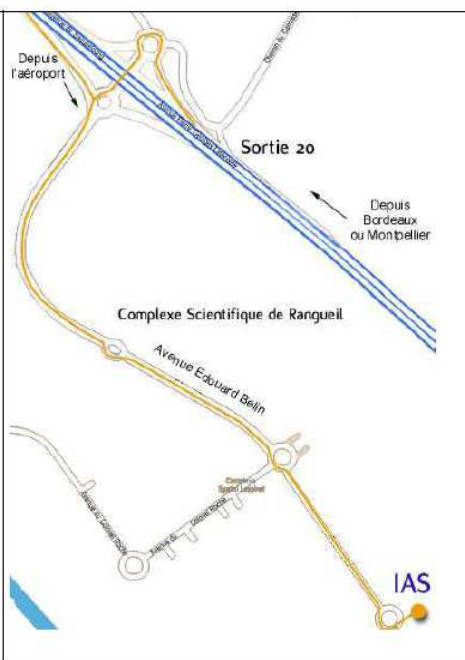
From Blagnac Airport:

East ring road : exit towards Toulouse Centre –FOIX/TARBES then exit 20/Complexe Scientifique de Rangueil

West ring road : towards Montpellier, then exit 20/Complexe Scientifique de Rangueil.

By TAXI :

Ask for « Complexe Scientifique de Rangueil» and mention to the driver IAS, 23 avenue Edouard Belin, next to CNES main entrance



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