

Workshop on

# Nonlinear Uncertainty Propagation using Differential Algebra

*European Space Research and Technology Centre*  
*ESA/ESTEC*

22 September 2015

## What are we?

We are an Italian consulting company operating in the aerospace sector



## Who are we?

We are a team of high-qualified engineers with a strong expertise in the aerospace field

## What do we do?

We are devoted to developing cutting-edge solutions and products for our clients based on their most challenging needs, striving for effectiveness and excellence



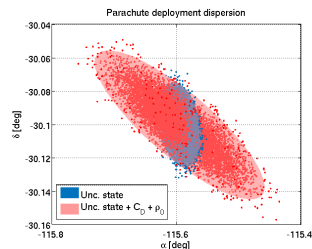
*Our purpose is to carry on  
developing methods and  
advanced solutions within  
the space field and to  
implement their use in other  
industrial sectors, therefore  
bridging the gap between  
academies and industries*



# WHERE YOU FIND US

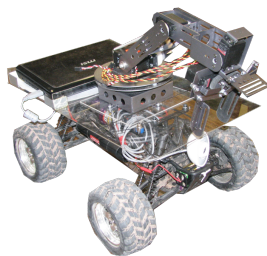
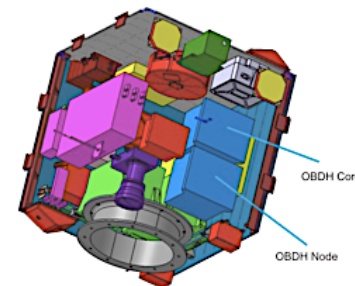
## UNCERTAINTY MANAGEMENT

- Uncertainty propagation
- Robust design
- Performance Analysis



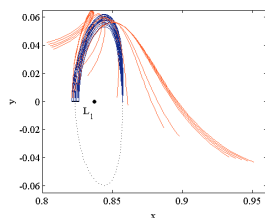
## SPACE SYSTEM DESIGN

- Concurrent design
- System Engineering
- Small spacecraft design



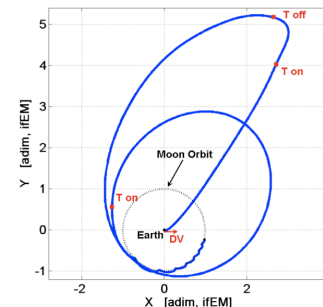
## AUTONOMY

- Planning/scheduling
- Artificial vision
- Rover path planning



## OPTIMIZATION & OPTIMAL CONTROL

- Global & local optimization
- Robust GNC for proximity operations
- Controller synthesis & analysis



## MISSION ANALYSIS

- Low-thrust trajectory design
- Atmospheric phases
- Formation flying
- Non-Keplerian Orbits
- EoL strategy

- Uncertainty propagation is a crucial issue in spaceflight dynamics
  - Space surveillance and tracking
  - Reentry and casualty area computation
  - Robust design
  - ...
- Most spaceflight mechanics problems involve **nonlinear behavior**



Need of efficient tools for **nonlinear propagation of uncertainties**

- In April 2013, ESA released the ITT-7570:

Non-linear propagation of uncertainties in space dynamics  
based on **Taylor differential algebra (DA)**

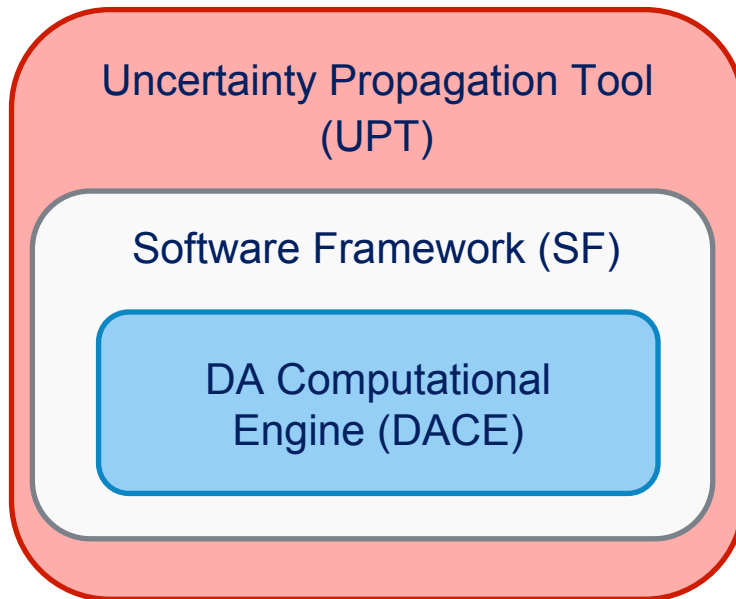



- Main objectives
  - To develop a **DA-based computational engine** to perform high-order computations efficiently
  - To add an uncertainty analysis that uses the computational engine to **propagate uncertainties in ready-to-use and custom applications**





## Differential Algebra Space Toolbox



- **DA computational engine**   
Implements Taylor DA arithmetic to handle polynomial operations
- **Software Framework**  
Provides all routines to perform DA based propagation in astrodynamics
- **Uncertainty Propagation Tool**  
Provides all routines and an interface for DA-based propagation of uncertainties

# MAIN OBJECTIVES OF THE WORKSHOP

- The main objectives of the workshop are:
  - To bring together engineers and researchers working on uncertainty propagation in space dynamics
  - To introduce Taylor DA and its potentials with respect to classical approaches in uncertainty propagation
  - To introduce DACE and DAST to the community and give a practical demonstration through the hands-on session
  - To discuss advantages and disadvantages of the approach with the aim of promoting common plans for future software development



## ■ Morning Session

- 9.45 - 10.15: Introduction to Differential Algebra - *A. Wittig*
- 10.15 - 10.45: Differential Algebra Comp. Engine (DACE) - *M. Massari*
- 10.45 - 11.00: *Coffee break*
- 11.00 - 11.30: Uncertainty Propagation Using DA - *R. Armellin*
- 11.30 - 12.30: Differential Algebra Space Toolbox (DAST) - *M. Rasotto*

## ■ Demo Session

- 14.00 - 15.15: Hands-on Demo Session on DAST
  - 15.15 - 16.00: Hands-on Demo Session on DACE
- ] *G. Di Mauro*

- Planned official release for DACE: **December 2015**
- Binary downloadable from ESA/Dinamica website
- Available on:
  - Windows
  - Mac OS
  - Linux
- License:
  - DACE: free for non-commercial use
  - Contact Dinamica for DAST and other uses of DACE



# Contact Information

## Operational Headquarters

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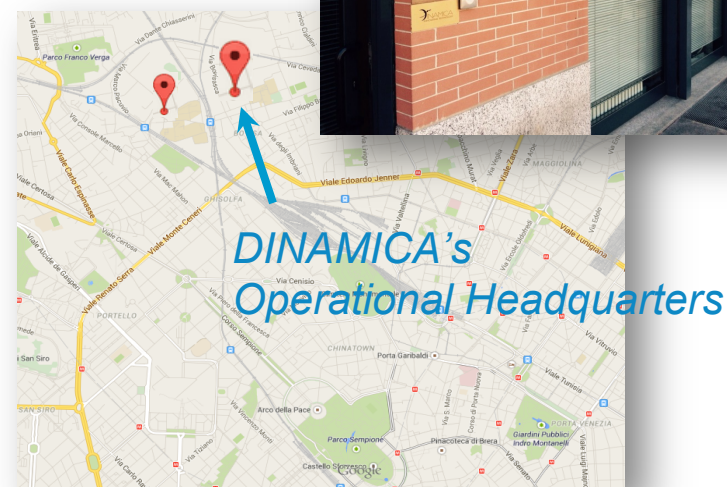
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