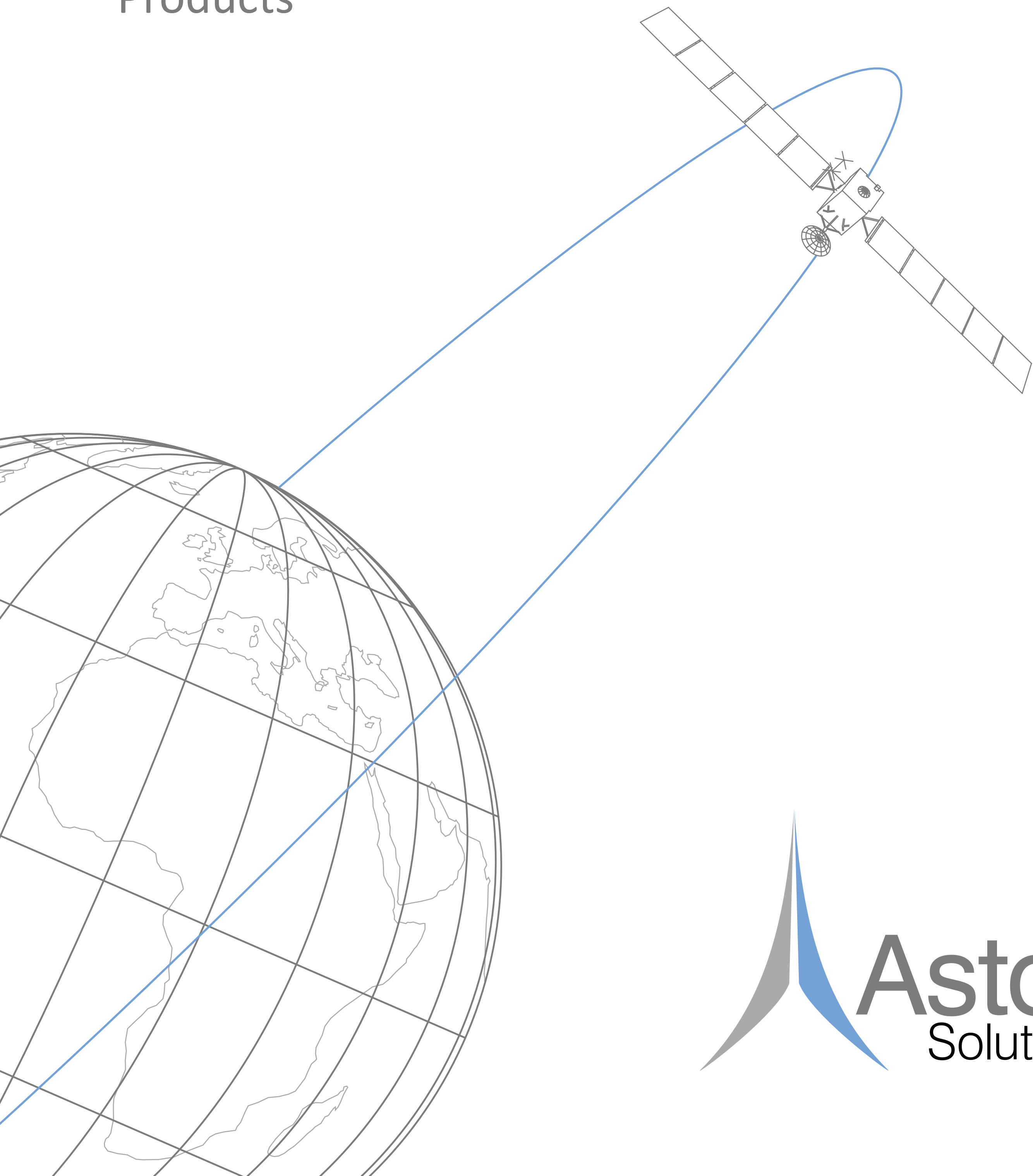
Leadership requires solutions

Experience
Solutions
Products



Astos Solutions


Astos Solutions site in the House of Aerospace in Stuttgart, Germany

Our Company

company

Overview

The aerospace company Astos Solutions is working in the fields of mission analysis, guidance, navigation and control providing flexible services and innovative software solutions. With our profound knowledge the company is a centre of competence for optimization and an active source for technology transfers into the non-aerospace market.

Our company is based in the south-west of Germany with the head office in Unterkirnach and a site office in Stuttgart, located in the “House of Aerospace” of the “Stuttgarter Engineering Park” (STEP) very close to the University of Stuttgart. The company has about 15 employees with the core team working in Stuttgart.

Astos Solutions uses state-of-the-art technology for communication, project management and quality assurance to ensure the highest possible standard in software development, customer support and project execution.

History

The history of Astos Solutions dates back to 1989, where under an ESA contract the development of the ASTOS software, former called ALTOS, has started at MBB, now Astrium, and DLR Oberpfaffenhofen. In 1991 the former project manager, Prof. Klaus Well, moved to Stuttgart, founded the Institute of Flight Mechanics and Flight Control (IFR) at the University of Stuttgart and continued with the development of ASTOS. In 1999 the first version was sold to industry and a transfer centre was founded, first at the Steinbeis-Transferzentrum and later at the TTI GmbH (Technology Transfer Initiative at the University of Stuttgart). After the retirement of Prof. Well in 2006 the business was completely transferred to the independent Astos Solutions GmbH, where all four employees of the original transfer centre are still working.

Since 1999 the ASTOS Software has been sold more than 30 times worldwide - mainly in Europe, but also in North and South America, South Korea and Japan.

Cooperation

Especially in the research area Astos Solutions is actively cooperating with mathematical institutes at universities all over Europe. Moreover a technology exchange is practised with DLR institutes. The software tools SOSE, PROMIS and TROPIC of DLR are integrated in ASTOS and the functionality of the sounding rocket simulator ROSI has been transferred into ASTOS.

Research & Development

Based on our research experience from university Astos Solutions continues with industrial research. The research concentrates mainly on numerical methods improving NLP solvers and transcription methods, which are used by optimization software, but integration algorithms and GNC algorithms are also investigated. Research activities are partly funded by the German Space Agency DLR and the European Commission within FP7.

Education

Astos Solutions supports the education of aerospace students actively. At the University of Stuttgart tutorials in optimal control are held for students accompanying the lectures. Moreover students are supported in their bachelor and master thesis or even in PhD works. They are working at Astos Solutions, at the University of Stuttgart or anywhere in the world.

Our Experience

experience

Astos Solutions has more than 10 years of experience in supporting industry, institutes and agencies in their optimization and mission analysis tasks. Altogether more than 20 launcher and 30 re-entry and exploration activities have been accompanied.
Especially the concurrent design facility of ESA/ESTEC has been intensively supported via ESA/ESTEC/TEC-EC. The following CDF studies are exemplarily mentioned:

- Heavy Lift Launch Vehicle
- Electric Upper Stage of VEGA
- Lunar Lander

Astos Solutions has managed several ESA projects as prime contractor with multiple subcontractors, like

- Non-Linear programming (NLP) solver for sparse trajectory optimization (eNLP)
- Mathematical optimization methods for concurrent early design of trajectory, propulsion and aerodynamics (CDO)

In various ESA and DLR projects Astos Solutions has participated as subcontractor, like

- Optimisation of station keeping manoeuvres for GEO satellites using electric propulsion
- New guidance schemes for TAEM of atmospheric re-entry
- LEO, a German Moon study
- ASTEX, feasibility study of an asteroid mission.

Astos Solutions has supported industry and institutions in trajectory optimization projects, like

- Reference trajectory of the German reusable launcher concept Hopper within ASTRA and FLPP (Astrium)
- Skylon, a reusable spaceplane concept of Reaction Engines, UK
- Thunderstar, a space tourism concept of Starchaser, UK
- USV (CIRA)
- VEGA launcher (ESA, ASI)
- OLEV, low thrust orbit transfer of various orbital life extension concepts
- Sharp edge flight experiment SHEFEX 2 and 3 (DLR)

Several times safety and risk analysis have been performed, like for the FLPP program and DEOS Phase A, a German orbital servicing mission.
In order to build up competences, Astos Solutions has performed extensive internal studies in the field of

- Orbital rendezvous
- Formation flying in high elliptical orbits (PROBA 3)
- Sounding rockets
- Navigation algorithms

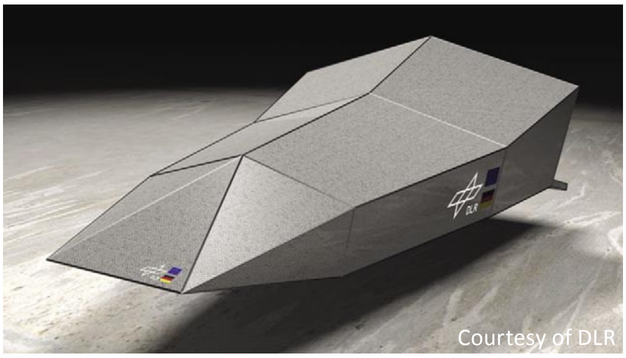
Astos Solutions has supported two flight missions:

- The MAXUS-8 launch from ESRANGE with the SHARK payload, where the landing ellipse has been reconstructed
- ATV-JV re-entry, where the ASTOS software was nominated by an ESA task force to be used for uncontrolled re-entry of ATV-JV. Moreover an ASTOS employee participated in the JV-MAC observation campaign of NASA to follow and analyze the break-up of ATV-JV.

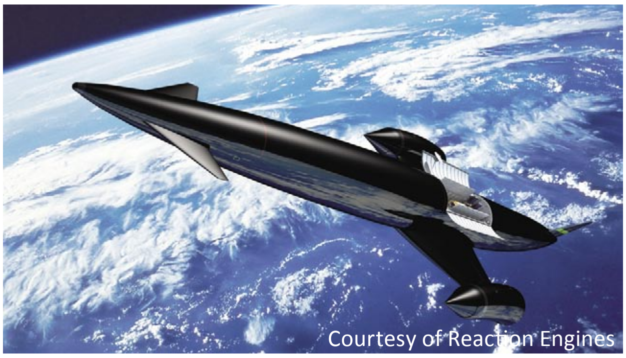
ASTEX

A German asteroid feasibility study investigated an in-situ mission to visit two near-Earth asteroids with Astos Solutions being responsible for:

- Pre-selection of 4 missions out of app. 5000 asteroids
- Analysis and selection of low thrust electric propulsion concepts
- Detailed low thrust trajectory optimisation and mission analysis
- Orbit definition and mission analysis in the proximity of the target asteroids



Model of Shefex 3



Skylon advanced spaceplane concept

Lunar Exploration Orbiter

The German Moon study LEO investigated an orbiter in a 50 km polar Moon orbit. Astos Solutions performed the mission analysis tasks in phase 0 and A within the Astrium consortium:

- Launch window calculations
- Trajectory optimization of various transfer concepts with delta-V-budget, injection and correction manoeuvres and circularization into the final Moon orbit including sensitivity analysis
- Orbit lifetime determination with Monte Carlo analysis considering uncertainties in the lunar gravity field
- Orbit keeping strategies

Orbital Life Extension Vehicle

Astos Solutions has profund experience in optimizing GTO-GEO low thrust orbit transfers for various OLEV concepts, like coneXpress, CX2 and SMART-OLEV. Based on the sparse optimizer SOCS optimal solutions can be provided within minutes. Detailed analysis has been performed for

- Slew rates
- Initial orbit conditions
- Collision avoidance with assets in the GEO-ring

Shefex

The DLR program Shefex develops solutions for re-entry vehicles at hypersonic velocities using unconventional shapes comprising multi-facetted surfaces with sharp edges.

The 6-dof simulation capabilities of ASTOS have been applied to MASER 11 and SHEFEX 2. The results have been validated by the comparison with the DLR reference tool and with the GPS data of the accomplished mission. Through the optimization of the SHEFEX 2 parameters, an alternative trajectory has been computed with a 20 % increase of the experimental time.

Following these interesting results, ASTOS has been selected as reference tool to simulate and optimize the third SHEFEX mission: a sounding rocket able to place a small satellite in orbit. Born from collaboration between DLR and the Brazilian Institute of Aeronautics and Space (IAE), phase B of SHEFEX 3 has been approved.

Beagle IV

The Beagle IV amateur rocket, also known from the Sony Rocket Project, has been built under the supervision of Rocket Mavericks. The nominal trajectory and the dispersion analysis required to fill out the FAA safety waiver application was entirely performed with ASTOS.

Our Solutions

solutions

Astos Solutions provides engineering solutions for

- Optimization problems
- Identification tasks
- Mission analysis
- GNC design and analysis
- Safety and risk calculations
- Database management

in the fields of

- Launchers
- Re-entry
- Vehicle design
- Telecommunication
- Earth observation
- Exploration
- Demonstration missions
- Space situation awareness
- Sounding rockets

Optimisation

Astos Solutions is most known in the field of trajectory optimization, based on the growing recognition and distribution of the ASTOS Software.
Trajectory optimization for ascent, re-entry and orbit transfer is considered as a so-called optimal control problem, which is solved by an optimisation algorithm. Therefore the dynamic system of a space scenario is described by a set of ordinary differential equations, an attitude control, which is usually discretized for purpose of optimization, and models representing the environment and the vehicle subsystems. Boundary and path constraints together with objective functions complete the definition of the optimization problem.
Classical problem formulations normally optimise the payload, fuel or lift-off mass as well as cross- and down-range, but also advanced tasks can be executed.

Examples are:

- Extension of the experimental time of a science mission
- Determination of minimum possible flight loads of a vehicle
- Computation of performance maps of launchers in batch mode
- Determination of entry and landing windows
- Solving complex geometric requirements of sensors
- Vehicle design in combination with design parameters

Multidisciplinary design optimization is useful in early design phases and requires scalable vehicle models combined with optimization techniques, which are able to handle dependencies between the different disciplines. Using fast and accurate models in a common optimization and simulation environment enables an efficient vehicle design process due to

- Fast computation of initial designs
- Consideration of interdisciplinary dependencies
- Reduction of the number of design loops

Optimization technology can be used also for identification purpose. For example:

- Flight trajectories reconstruction based on navigation data
- Aerodynamic coefficients determination based on flight data
- Magnetic field computation based on measurements

Up to now the potential of optimization as a basic technology for answering engineering questions is not fully recognized. Instead of manual trial and error approaches, optimization techniques can help to explore the solution space, optimal results, sensitivities and the quality of robustness. Thereby optimisation can improve the quality of results and reduces the demand of manpower.

Safety Analyses

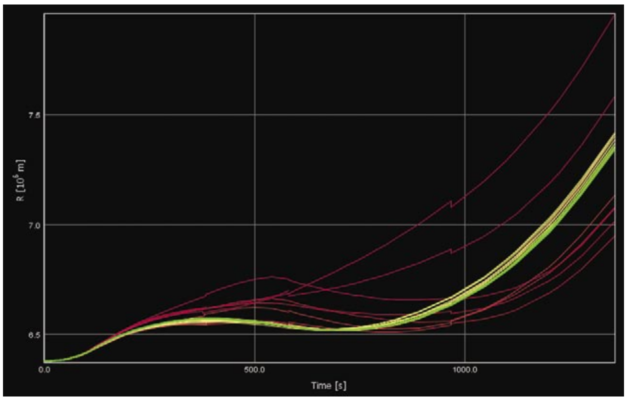
Safety of humans and assets is essential for space mission design and mission operation. Risk due to spacecraft re-entry as well as in-orbit collision risk is covered by our safety analysis solutions. Our re-entry risk tools, which have been already used by ESA for ATV-1, consider the following safety aspects:

- Casualty and fatality probability for on-ground population
- Impact probability for ships and airplanes
- Casualty and fatality probability for aircraft passengers
- Maximum probable loss

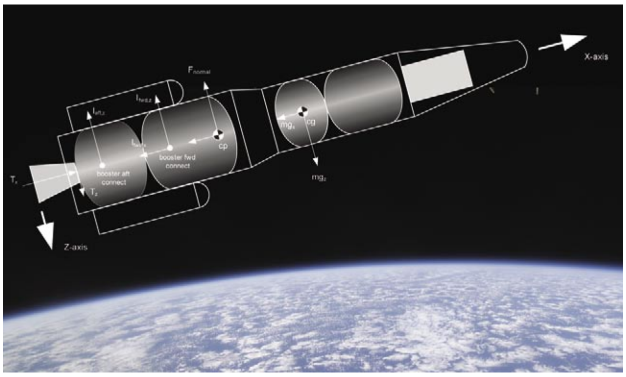
The corresponding re-entry simulation that predicts the impact locations considers

- Aerodynamics
- Aerothermal processes
- Fragmentation
- Explosion
- Melting and demise of fragments
- Material properties of individual fragments

All analyses may be incorporated into a Monte Carlo simulation that covers a multitude of uncertainties.
Our in-orbit collision risk assessment is based on NORAD catalogue data that is extended by uncertainty information. The analysis provides a list of risk imposing objects due to close encounters and the collision probability of these objects.



Iteration monitoring of the altitude (radius) profile while optimizing a launcher mission with ASTOS



Structural analysis as part of a launch vehicle design

GNC Design and Analysis

Based on the guidance and control experience of the IFR, Astos Solutions continues working in the field of re-entry guidance. Various algorithms have been developed for lifting body re-entry in the hypersonic regime and for TAEM guidance. Currently on-board trajectory reshaping algorithms for future transport vehicles (spaceplanes) are investigated within the FP7 activity FAST20XX.

Astos Solutions invests into the research of GNC and AOCS algorithms for orbital scenarios such as guidance and navigation algorithms for rendezvous and exploration. Image processing and optical navigation techniques are currently under development. Several applications are targeted:

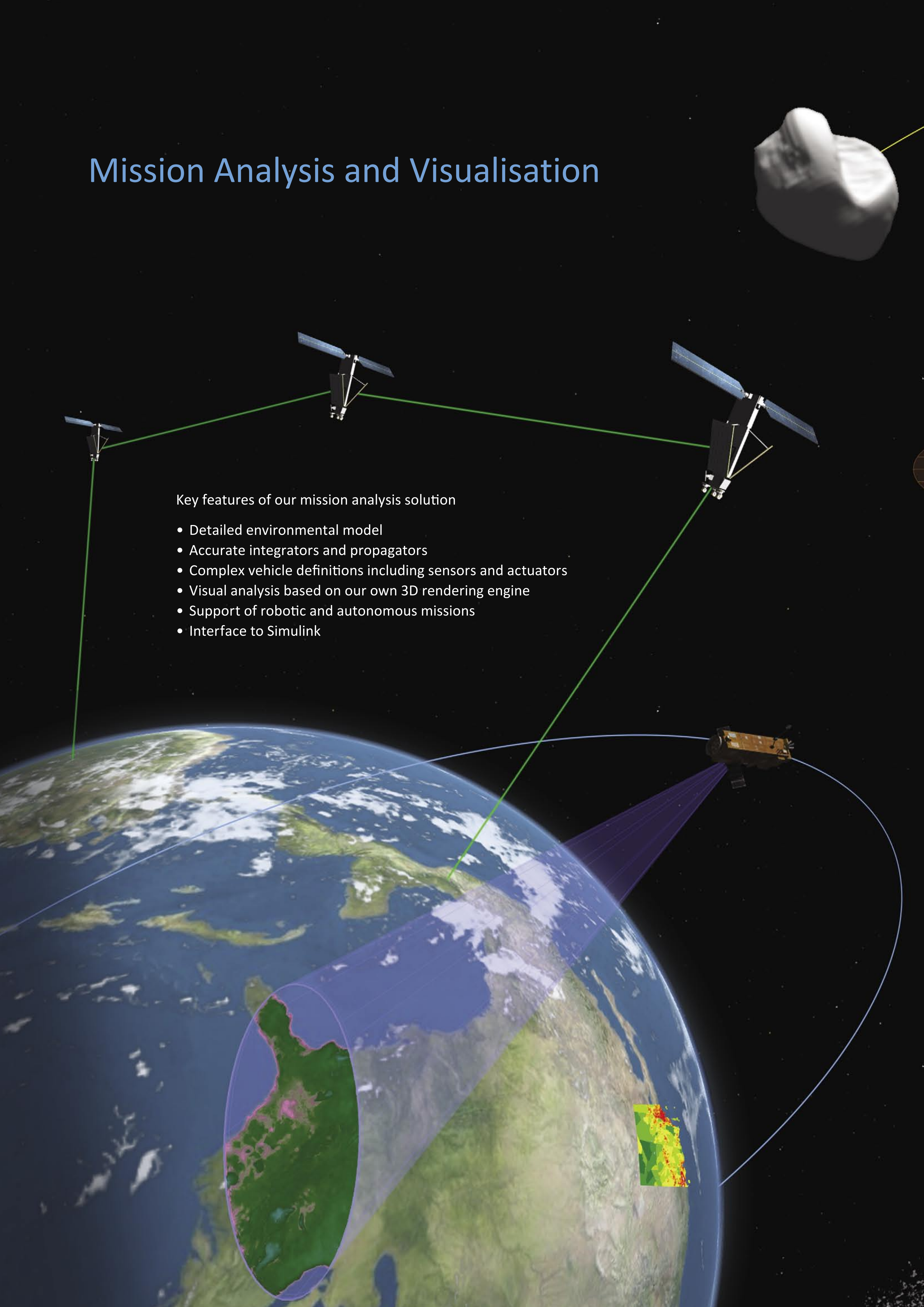
- Identification of the transversal and rotational motion of a disobliging satellite (e.g. for OLEV scenarios)
- Autonomous landing with boulder detection
- Tracking of observed re-entry objects

Impact analysis during a sounding rocket campaign. The picture shows the different results: on the left screen the nominal trajectory, altitude, Mach number and flightpath speed vs. time and on the right screen the impact footprint of a dispersion analysis.

Mission Analysis and Visualisation

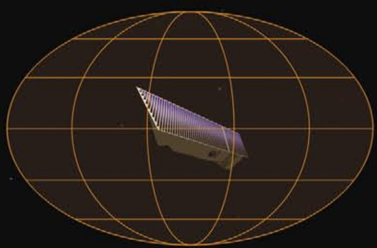
Key features of our mission analysis solution

- Detailed environmental model
- Accurate integrators and propagators
- Complex vehicle definitions including sensors and actuators
- Visual analysis based on our own 3D rendering engine
- Support of robotic and autonomous missions
- Interface to Simulink



We can offer solutions for the complete mission analysis work package

- Departure & arrival window
- Delta-V budget
- Manoeuvre planning
- Fly-by analysis
- Eclipse analysis
- Visibility analysis
- Subsystem analysis
- Scientific environment analysis
- 6-dof related analysis in combination with AOCS design
- Sensor field of view analysis



Unmatched visualisation capabilites with realistic appearance of celestial bodies:

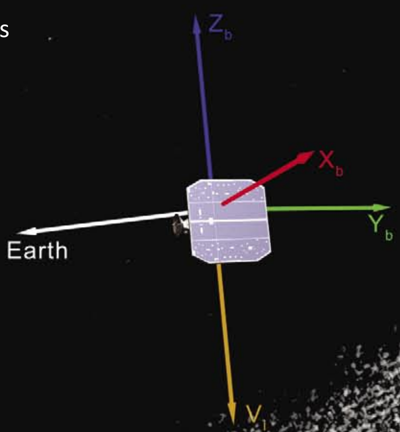
- Texture
- Shadow
- Reflexion of light from surfaces (e.g. regolith, water or ice)
- Light scattering through atmosphere
- Clouds

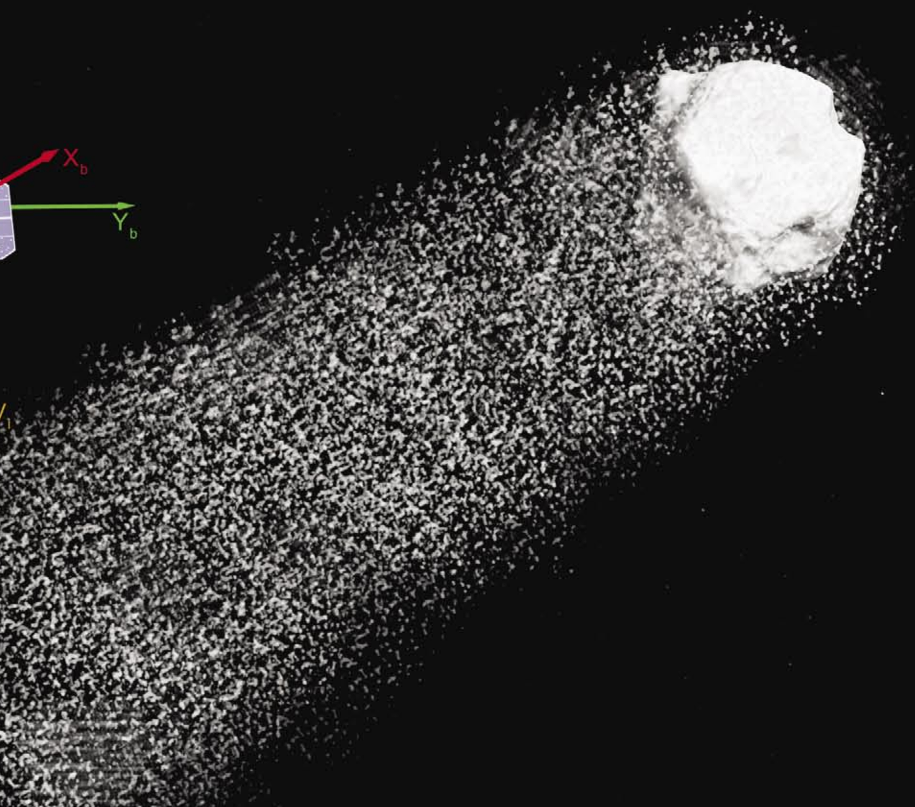
and – important for analysis of visibility – detailed representation of space crafts and launch pads:

- Texture
- Shadow
- Reflexion from surface depending on material
- Effects during reentry (heat, shock wave)

Visual aids supporting the mission analysis

- Coverage
- Visibility
- Field of view
- Antenna beam
- Attitude
- Conjunctions
- Vectors
- Trajectories
- Frames
- Overlays





Our Products

products

Astos Solutions develops and distributes several COTS software:

- ASTOS, simulation and optimization of aerospace scenarios
- GESOP, a general platform for simulation and optimization of dynamic systems
- POINT, a program to optimize interplanetary trajectories
- GAMAG, a software to calculate the magnetic cleanliness of satellites and to compute compensations of the magnetic field
- SOCS, an optimizer licensed by the Boeing Company and distributed by Astos Solutions worldwide

All software is available on a variety of platforms, including Windows, Linux and MAC, and is provided with the FLEXlm license manager, which allows node locked and floating licenses.

ASTOS

The AeroSpace Trajectory Optimisation Software ASTOS is, originally developed for launcher ascent, suited to analyse a wide range of aerospace missions from atmospheric over orbital to interplanetary scenarios. It can be used for fast preliminary design studies as well as for operational tasks with high requirements for accuracy. Possible applications are:

- Performance calculations
- Feasibility studies
- Trajectory optimization
- Mission design
- Preliminary vehicle design
- Concept verification
- Sensitivity analysis
- Detailed mission analysis
- Support of operations

The particular ability to combine any analysis task with optimization allows the user to solve a problem faster and more accurate than by performing a manual trial and error approach. This is supplemented by the integrated Batch Mode Inspector, which enables fully automatic process execution of most ASTOS actions – a key feature for robustness analysis!
A graphical user interface allows the complete data driven definition of the space scenario, which includes:

- The vehicle as a set of components, propulsion systems and aerodynamics
- The mission environment with central body, atmosphere, wind and perturbation sources like third body gravity sources or solar wind
- The initial state and time
- A phase sequence defining the utilization of the vehicle systems, the used attitude control and active environment

ASTOS provides easy-to-use interfaces to user coded modules for most of the vehicle systems. Through such interfaces 3rd party libraries have been linked to ASTOS, e.g. the NASA libraries Gram99, MSIS, SPICE and others.
Import and export functions are provided for tools like Excel and Matlab. Extensive plotting and reporting capabilities make ASTOS a comprehensive analysis tool.
ASTOS further provides optional modules for special purpose:

- The Branching function that can consider parallel flight arcs for missions with separations, e.g. RLV, abort manoeuvres or multi mission vehicle design
- Safety & Risk with DIA, DARS and RAM for deterministic and stochastic debris and risk analysis
- Detailed Vehicle Design dedicated for design of launch and re-entry vehicles including geometry models, SOSE aerodynamics and CEA interface

ASTOS fulfils highest quality requirements considering standards like ECSS, CCSDS, IAU and MIL-STD.

POINT

The Program to Optimize INterplanetary Trajectories provides several flexible methods to model and optimize interplanetary trajectories:

- Patched conics with optimizable fly-by bodies
- Multi-conics with a reduced model of the 3-body problem considering perturbations
- Exponential sinusoids for low thrust missions
- Detailed modelling and refinement of the trajectory and optimization with SOCS

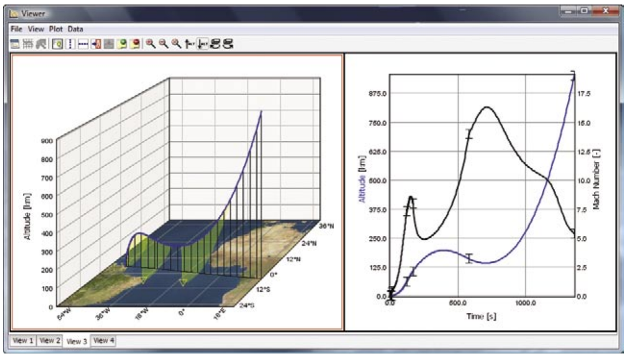
A library provides the application with detailed models of spacecraft components like propulsions and power generators as well as events such as flybys, stopovers and deep space manoeuvres. The proven Batch-Mode capability of POINT allows precise and automatic analysis of thousands of missions.

GESOP

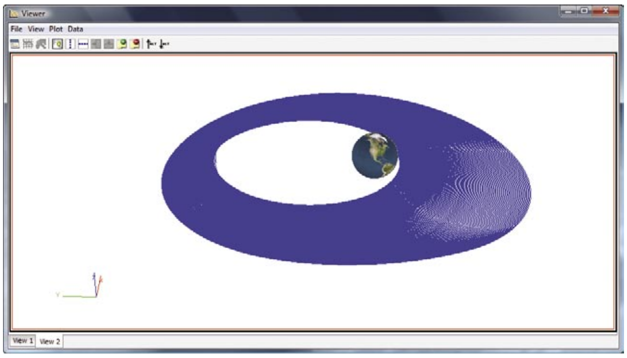
The Graphical Environment for Simulation and Optimization serves as a platform for ASTOS, POINT and other tools. It can also be used stand-alone and the user can easily link own models. GESOP provides a complete set of integration and optimization algorithms and high quality plotting capabilities. The provided local optimizers are PROMIS, TROPIC, CAMTOS and SOCS, which offer direct collocation as well as multiple shooting methods. They utilize the NLP solvers SLLSQP, SNOPT and eNLP, which enable the user to handle up to 10,000 parameters. The sparse NLP solver of SOCS allows even more than 200,000 parameters. Global optimization can be performed with the genetic algorithm CGA.
The objective of GESOP is to provide the user a clear programming interface, which is defined very close to the engineering problem. No special knowledge about the mathematics of optimization algorithms is required.
GESOP provides interfaces for a set of ordinary differential equations, which can be solved numerically or analytically. Additionally control laws, boundary and path constraints and objective functions define the optimization problem.

GAMAG

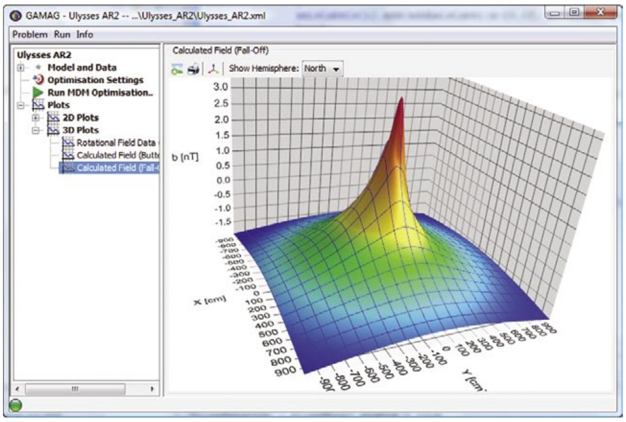
The GAMAG software is an advanced analysis tool of magneto-static fields measured around a test object. A set of magnetic dipole parameters is identified according to field measurements. It is used to calculate the field vector as well as the global dipole moment of the test object.



Ascent optimization with ASTOS



ASTOS orbit transfer optimization



Magnetic field identification with GAMAG

GAMAG is a fully automatic analysis tool with the following features:

- Graphical user interface with sophisticated 3D-plots
- Fully automatic initial guess generation of dipole parameters
- A precise solution with the minimum number of necessary dipoles
- Fast convergence time suited for on-line computations
- The variance of the field at the specification point computed by statistical analysis
- A precise compensation of the magnetic field at the position of the specification point

Astos
Solutions

http://www.astos.de
service@astos.de

Headquarters:
Astos Solutions GmbH
Grund 1
78089 Unterkirnach
Germany
Tel. +49 (0) 77 21 - 501 42
Fax +49 (0) 77 21 - 501 43

Office Stuttgart:
Astos Solutions GmbH
Haus der Luft- und Raumfahrt
Meitnerstr. 8
70563 Stuttgart
Germany
Tel. +49 (0) 711 - 89 26 33 - 00
Fax +49 (0) 711 - 89 26 33 - 01