Entry Descent and Landing Tools

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Introduction

Vorticity

- Privately owned SME (est. 2001)
- Specialising in space vehicle EDLS
- Recent experience:
  - ESA/Alcatel - Huygens DCSS
  - NASA - Hypercone
  - ESA - Mercury Landing Technologies
  - ESA/Alcatel - ExoMars Phase A
  - ESA/SSTL – Earth Return Vehicle Demonstrator
  - ESA - Alternative Descent & Landing Technologies
  - ESA - Venus Entry Probe Study
Simulation Aims

Entry
- Trajectory and dispersions
- Aerothermal heating estimation
- Accelerations / loads / pressures
- Entry stability / dynamics

Descent
- Trajectory and dispersions
- Sequencing / deployment
- Parachute loads / accelerations
- Stability / dynamics / wind effects
Simulation Aims

Landing

- Airbags
  - Terrain
  - Impact dynamics / terrain clearance
  - Landing success probabilities
  - Detailed airbag pressures / loads / stresses
  - Thermal performance
  - Leakage effects
  - Release dynamics
  - Retraction
Entry Trajectory – Trajectory3D

- Object oriented C++ code
  - XML data driven
- 3D trajectories of entry vehicles
- Multiple atmospheres
  - Earth: GRAM
  - Mars: MarsGRAM or EMCD
  - Venus: VIRA / Sieff
  - Titan: TitanGRAM
- Monte-Carlo / sensitivity options
  - dispersions
Entry Trajectory – Trajectory3D

- Mass evolution throughout trajectory
- Initial aerothermal predictions
  - Convective flux: Sutton-Graves correlations
  - Radiative flux: Tauber-Sutton correlations
- Parachute / inflatable decelerators
  - Decelerator deployment / inflation simulated
  - Inflation load predictions
- Sequences
  - Unlimited parachutes / released objects
  - Flexible sequencing by acceleration, Mach, height and time
Entry Trajectory / Dynamics – Trajectory6D

- Object oriented C++ code
  - XML data driven
  - Coupled multiple bodies
- 6DOF simulations - trajectory / stability of entry vehicles
- nDOF simulations of descent systems
- Multiple atmospheres
- Monte Carlo
- Wind
Entry Trajectory / Dynamics – Trajectory6D

- Complete modelling of parachute dynamics
- Modelling of bridles / attachments
- Retro-rockets / TIRS type systems
Parachute Performance

- **Inflate**
  - Rapid prediction of parachute inflation loads / stresses
  - Subsonic / supersonic
  - Large range of parachute types
  - Built into Trajectory3D and Trajectory6D

- **Deploy**
  - Rapid simulation of parachute deployment dynamics and snatch loads
  - Built into Trajectory3D and Trajectory6D
Airbag Design Environment

- Terrain generation
- Airbag parametrics
  - Stiffness
    - Stroke / load
- Monte Carlo Impact Success Predictions
  - Statistical
  - Terrain coupled
  - Cooling / Leakage
  - Failure metrics for ground impact of store, puncture, acceleration, rupture
- Allows rapid airbag sizing and pressure optimization
LS-DYNA Overview

Capabilities:

- General purpose finite element code;
- Primarily explicit time integration, limited implicit also available;
- Ideal for highly dynamic/large deformation scenarios;
- Large number of material models and element formulations;
  - Including some fully representative of airbag materials
- Specialized contact algorithms, airbag and fluid-structure interaction capabilities.
Entry Stability

- Determination of pitch damping $C_{mq}$
  - Very difficult to determine by wind tunnel test
  - Only ballistic range tests effective
- Good matches to Viking data obtained
Entry – Inflatables

- Inflatable entry systems
  - Inflation, structural loads
Entry – Inflatables

- Inflatable entry systems
  - Structural stability, aeroelastic / aerodynamic stability
Descent – Complex parachute behaviour modelling

- FSI simulation has stated to explain many parachute dynamic phenomena
Landing Systems - Airbag

- Impact dynamics
  - Mercury Landing Technologies airbag concepts
  - Rapid trading of stroke, g, pressure for multiple configurations
Landing Systems – Airbags

- Jettison