WORHP: We Optimise Really Huge Problems

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What is WORHP?

Modern Nonlinear Programming Solver

➢ Sponsored and in use by European Space Agency

➢ Sparse architecture without compromises

1 billion variables **+** **2 billion** constraints **=** **WORHP**

ESA requirements

"Core suitability [for] a broad range of application cases"

➢ Very general problem formulation

➢ Industry-standard robustness & usability

Selected application areas:

- Realistic flight simulation (AMST)
- Satellite constellation+operation optimisation (in-house)
- Low-Thrust trajectory verification (ESA/ESOC)
- Launch, reentry, rendezvous, flyby (ESA/ESTEC, Astos)
- Multi-Disciplinary optimization („SVAGO")
- High-dimensional fitting of characteristic curves (IAV)
- Multiobjective Optimization

3

Users (>200 total)

- Industry + Agencies
  - ESA TEC–EC
  - EADS Astrium
  - EADS Innovation Works
  - ESOC Darmstadt
  - CNES Paris (F)
  - DLR Bremen
  - DLR SchoolLab
  - DLR Oberpfaffenhofen
  - IFSTARR (F)
  - IAV
  - Ferrari
  - Volkswagen
  - Argonne National Laboratory (US)
  - Bayer Business Services
  - AMST (A)
  - Astos Solutions
  - AMPL Optimization LLC (US)
  - Fraunhofer MEVIS
  - Fraunhofer ITWM
 - …

- Universities
  - Tokyo Institute of Technology (JP)
  - Cornell University (NY, US)
  - SUNY Albany (NY, US)
  - Northwestern Polytechnical (PRC)
  - Hacettepe Üniversitesi (TR)
  - U Arizona (AZ, US)
  - U Houston (TX, US)
  - U Oxford (GB)
  - U Strathclyde (GB)
  - U Campinas (BR)
  - Politecnico di Milano (IT)
  - TU Munich
  - TU Berlin
  - U Bremen
  - U Bonn, INS
  - U Bayreuth
  - U Rostock
  - U Braunschweig
  - U Hamburg
  - …

Technical Overview

- Platforms: Linux, Unix, MacOS, Windows (both 32 and 64 bit)

- Compiles with GNU, Intel, VisualStudio

- User Interfaces: C, C++, Fortran95, Fortran2003, AMPL, Matlab/Simulink, Python

- Linear solvers: MA57, MA47, MA48, PARDISO, MUMPS, SuperLU, LAPACK

- Future plans: embedded (ruggedized, tablets, smartphones, …)

Performance

- Landing of a hypersonic flight system

- Fully discretized forward Euler

- 400000 variables, 320000 constraints, 1400s runtime
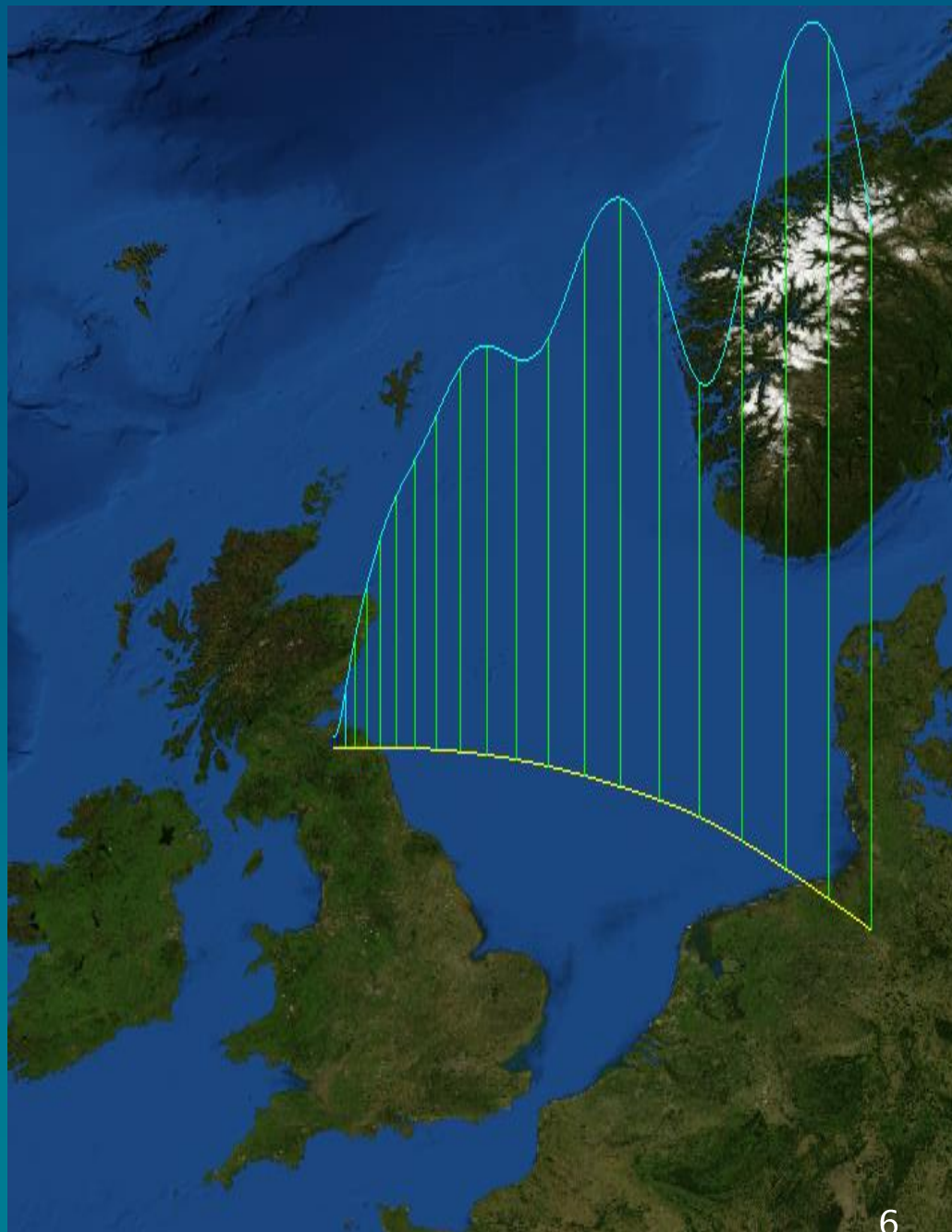
Further work: AWACS

Adaptation of WORHP to Avionics Constraints

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