Enhancement of DLR/GSOC FDS for Low Thrust Orbit Transfer and Control
GSOC Flight Dynamics System (GSOC FDS)

- Numerical orbit prediction / determination
- Generation of orbit related information
- Impulsive maneuvers & extended maneuvers (inertial / orbital frame) with **fixed** thrust direction
  - Long-lasting low-thrust transfers require **time dependent** thrust directions!
FDS Requirements

a) Easily extendable framework

b) Compliant with the existing FDS

c) Representation of low-thrust maneuvers via thrust profiles

d) Numerical orbit propagation of low-thrust phases to provide Orbit Related Information (ORI)

e) Orbit determination (OD) of low-thrust phases
FDS Design

- Orbit determination
- Thrust reconstruction
- Tracking data simulation

- State vector record(s):
  - Epoch, S/C parameters, maneuver data

- Ephemerides
- Events
- GS visibility / timeline plots
FDS Design

- Transformation of tracking data readable by OD software
- Reconstruction of thrust directions used within OD software
- Generation of optimized low-thrust profiles via ASTOS/GESOP software package
FDS Design

- Generation of attitude control data for upload to the satellite
- Development / Optimization of new station keeping strategies
- Consideration of collision avoidance maneuver(s) within transfer optimization
Sample GTO-to-GEO Low-Thrust Transfer (1)

- Ground station (GS) network: 3 stations spread over Europe, East Asia, North America

- 4 phases:
  1. Check out of S/C (several days)
     • 3 GS / permanent
  2. First phase of EP (1-2 weeks)
     • 3 GS / permanent
  3. EP cruise phase (~120 days)
     • 3 GS / ~2.5h per day
  4. Final EP phase (1-2 weeks)
     • 1 GS / permanent
Sample GTO-to-GEO Low-Thrust Transfer (2)

- ARIANE 5 transfer
- 2-ton class satellite
- $I_{sp} \approx 2600$ s
- Orbital elements:
  - $a = 24371$ km
  - $e = 0.73$
  - $i = 6.0^\circ$
  - $\Omega = \omega = M = 0.0^\circ$
- 1 low-thrust maneuver →
- Total $\Delta v \approx 2200$ m/s

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Thrust Level Reconstruction

Objective: Calibration of EP performance

- Propagation to day 11 at 0 UTC
- 48h simulation of angle / range measurements
- OD with perturbed thrust level

✓ Robustness of enhanced OD software against thrust level uncertainties
Retrieval of Satellite after Thruster Failure

- GS visibility for days 63 to 67
Retrieval of Satellite after Thruster Failure

- Satellite still visible
Retrieval of Satellite after Thruster Failure

Potential loss of satellite
Retrieval of Satellite after Thruster Failure

Station 1

- Beam requirement
- Pointing Offset
- Elevation

Begin of pass: 2013/10/11 21:04

Satellite now visible
Conclusion & Outlook

✓ Development & implementation of thrust profile format
✓ Enhancement of orbit determination software
✓ Enhancement of orbit-related information software

✗ Analysis of further low-thrust scenarios (LEO-to-GEO, GEO station keeping)
✗ Analysis of refined transfer trajectories including operational / technical constraints (thrust modulation, thrust interruption during eclipses)
✗ Consideration of collision avoidance maneuvers
Questions?

Thank you for your attention!