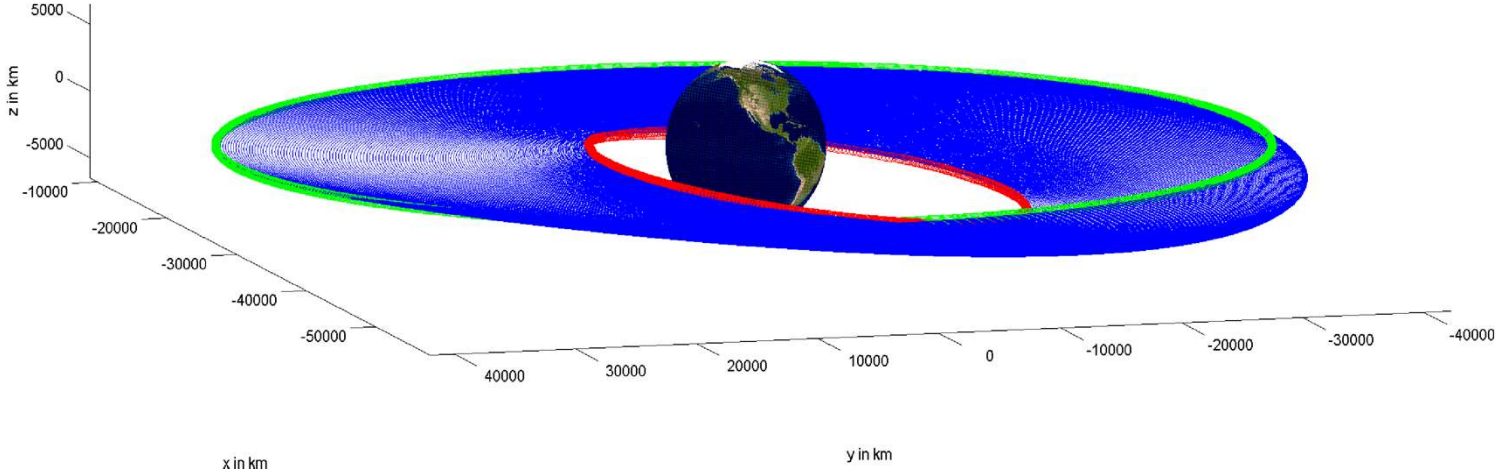
Enhancement of DLR/GSOC FDS for Low Thrust Orbit Transfer and Control

DLR

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

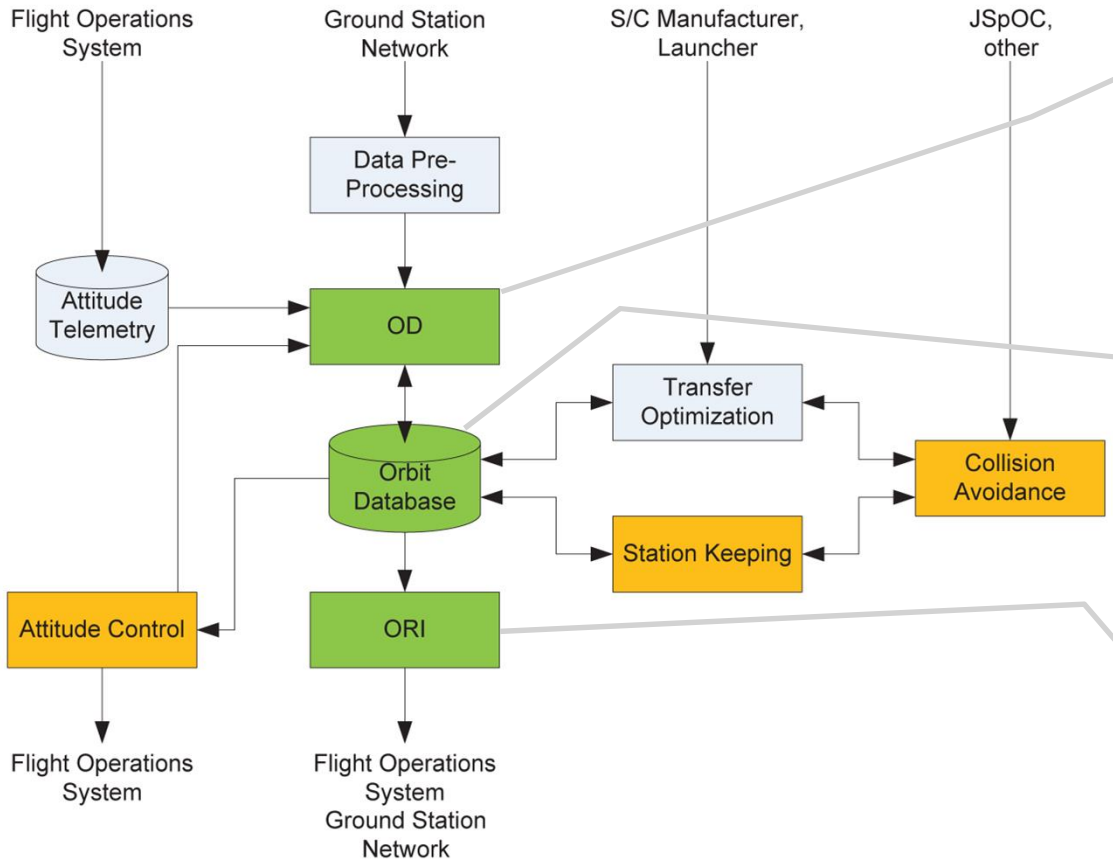
b) Compliant with the existing FDS

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

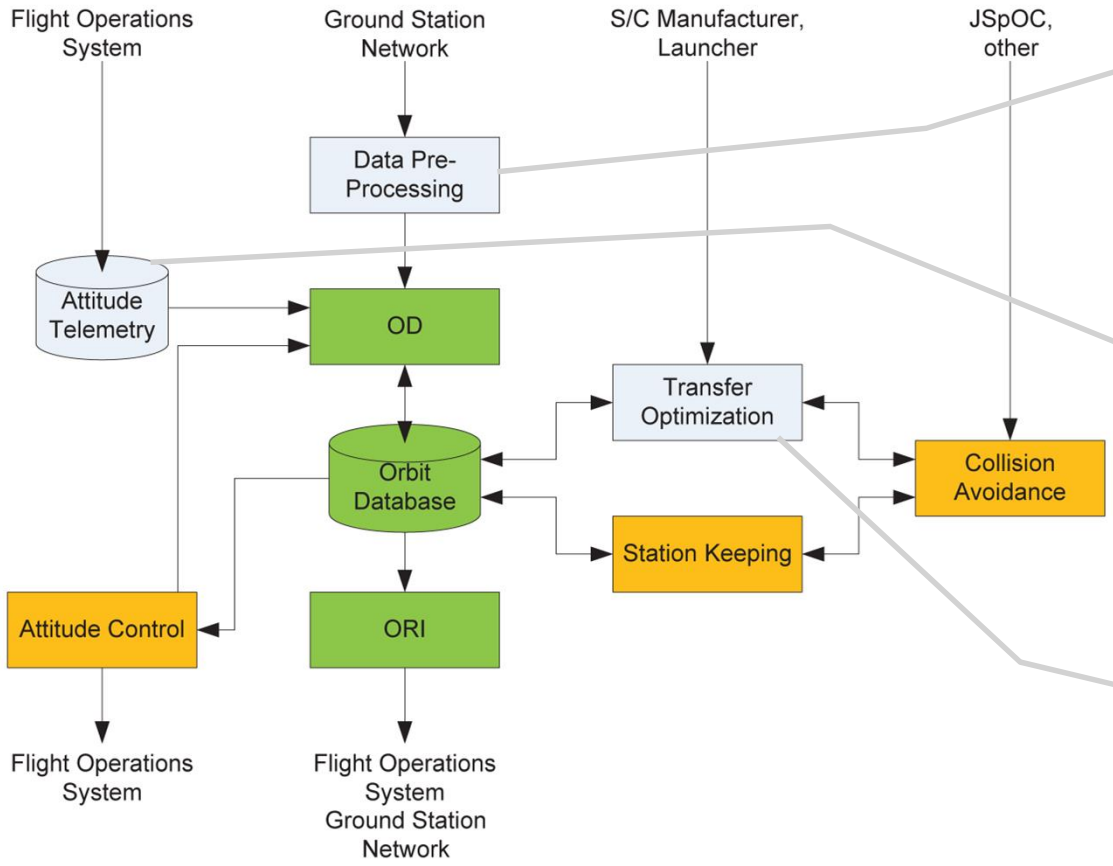


- Orbit determination
- Thrust reconstruction
- Tracking data simulation

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

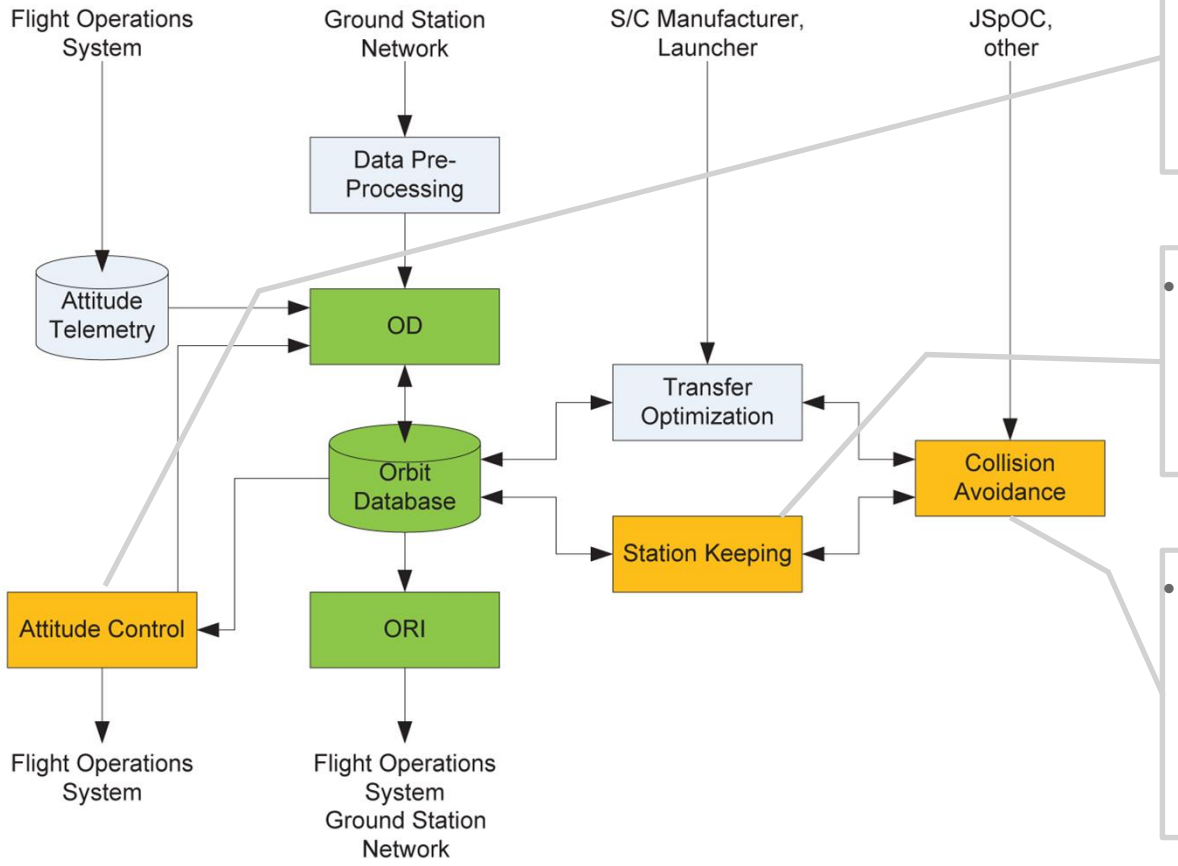
- Ephemerides
- Events
- GS visibility / timeline plots

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

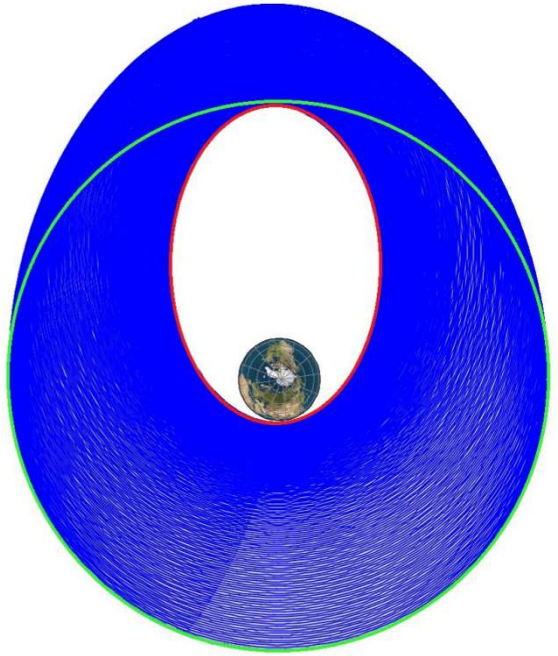
FDS Design



- Generation of attitude control data for upload to the satellite
- Development / Optimi-zation 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



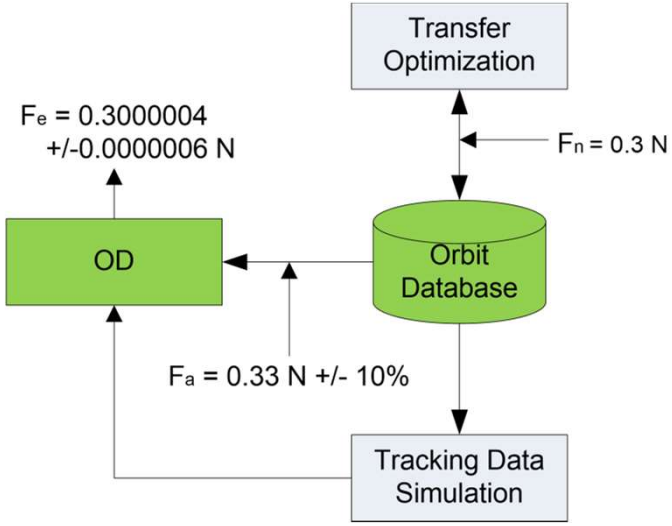
Sample GTO-to-GEO Low-Thrust Transfer (2)

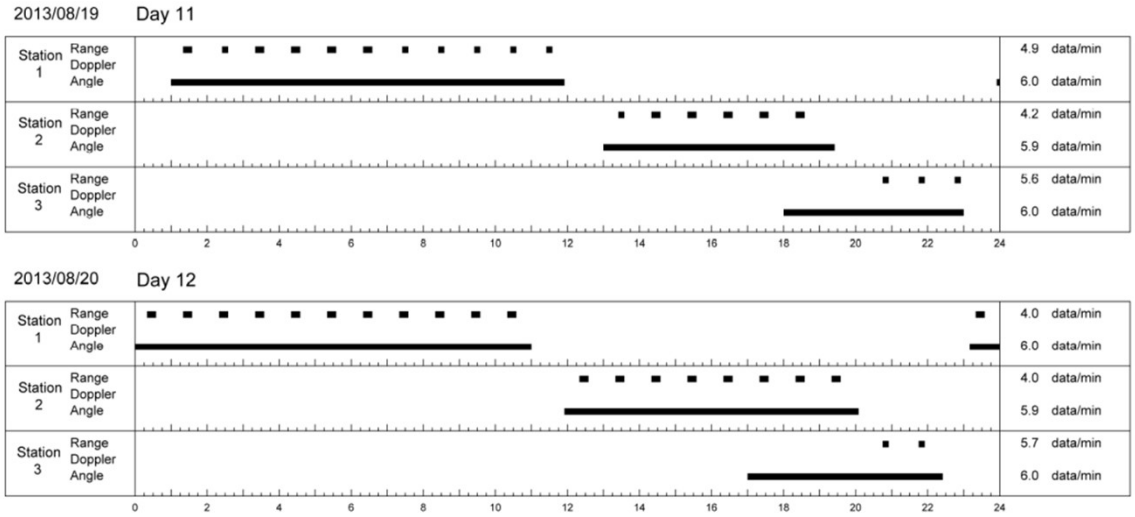
- ARIANE 5 transfer
- 2-ton class satellite
- $I_{sp} \approx 2600$ s
- Orbital elements:
  - a = 24371 km
  - e = 0.73
  - i = 6.0°
  - Ω = ω = M = 0.0°
- 1 low-thrust maneuver →
- Total Δv ≈ 2200 m/s

Epoch (UTC)			2013/08/08 23:59:34.3
Reference Frame			Inertial
Thrust level F_n $[N]$			0.3
Mass flow $[kg/s]$			0.000011766
No. of thrust records			3448
Time stamp $[ddd : hh : mm : ss.sssss]$	e_1	e_2	e_3
000:00:00:00.00000	0.00195	0.99951	-0.01475
000:00:00:54.24226	-0.05769	0.99722	0.02623
...			
138:17:22:15.19338	-0.04463	-0.99999	-0.17020
138:19:35:21.03387	0.12680	-0.99617	-0.13346

Thrust Level Reconstruction

Objective: Calibration of EP performance

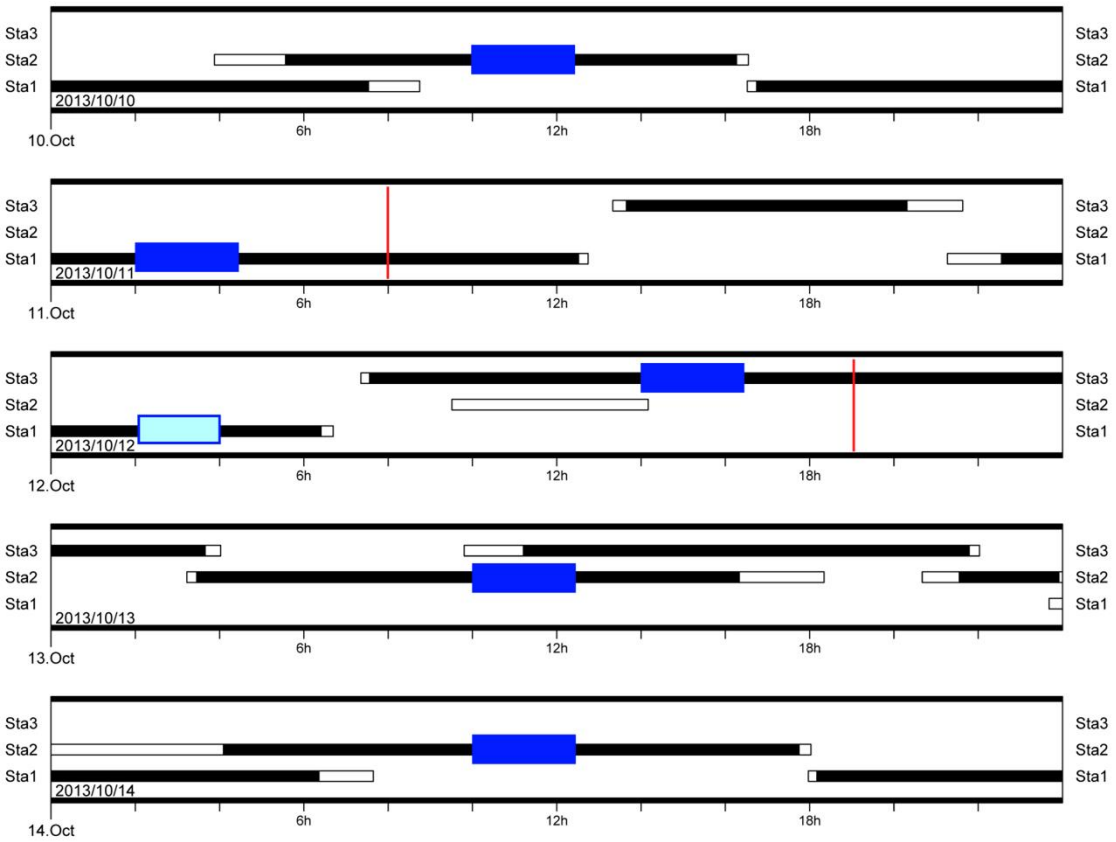




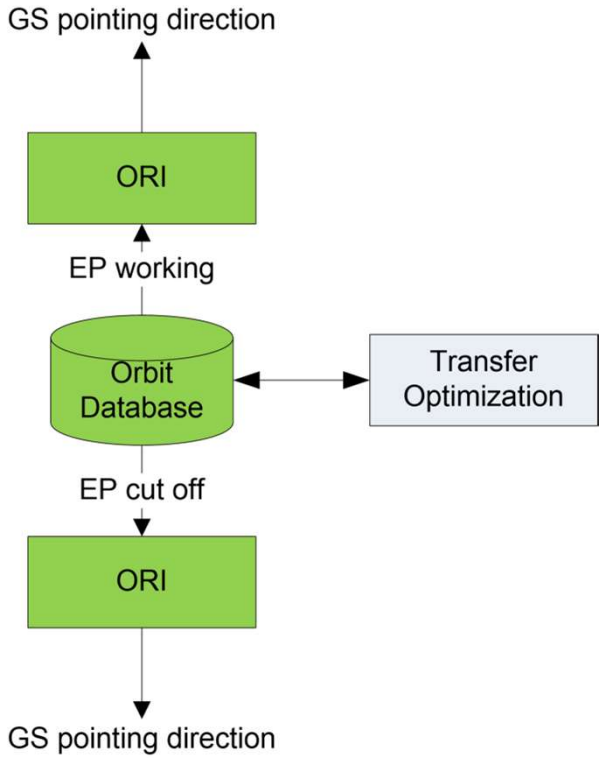
- Propagation to day 11 at 0 UTC
- 48h simulation of angle / range measurements
- OD with perturbed thrust level

✓ Robustness of enhanced OD software against thrust level uncertainties

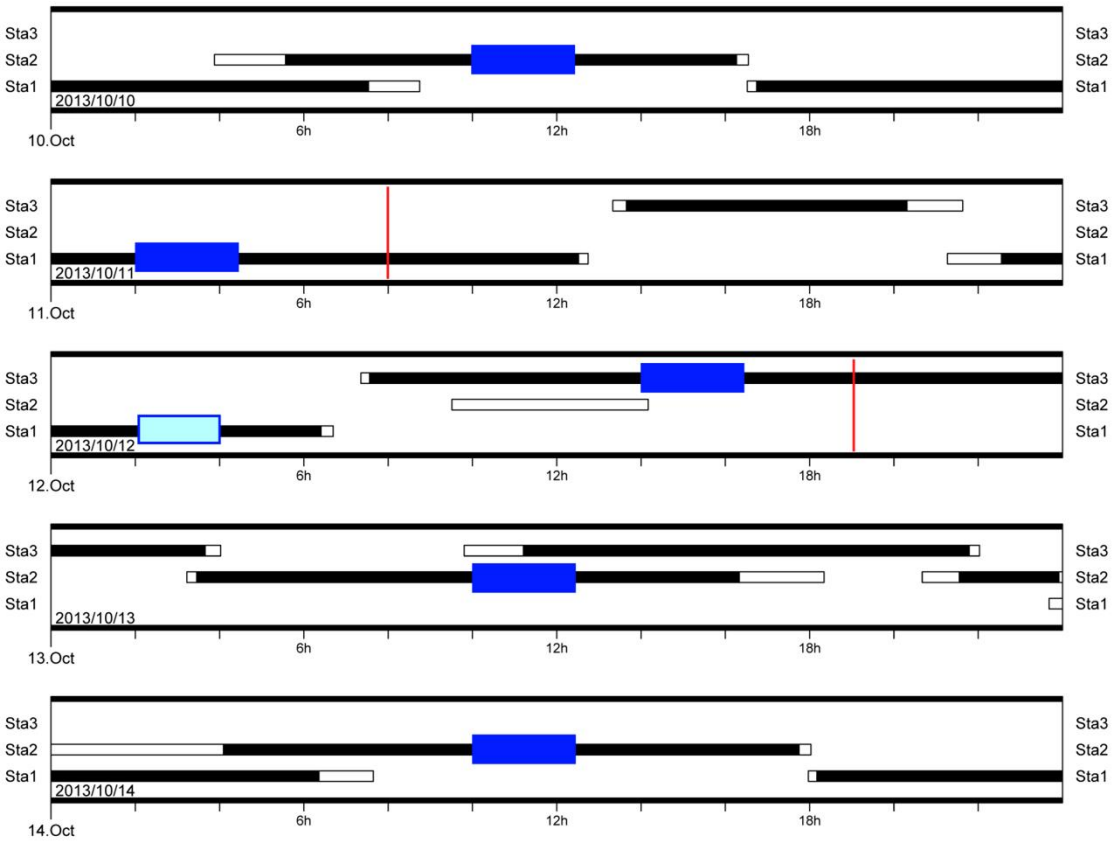
Retrieval of Satellite after Thruster Failure

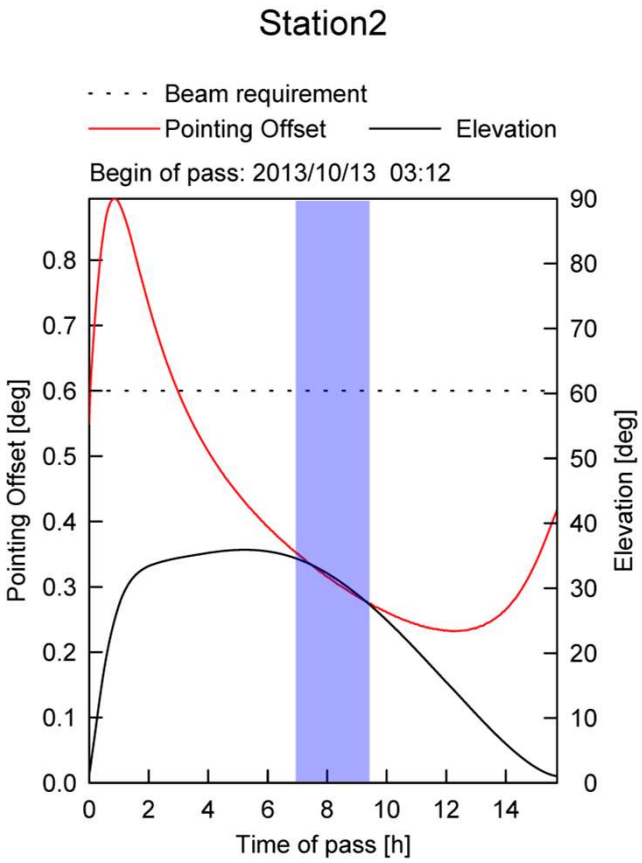


- GS visibility for days 63 to 67



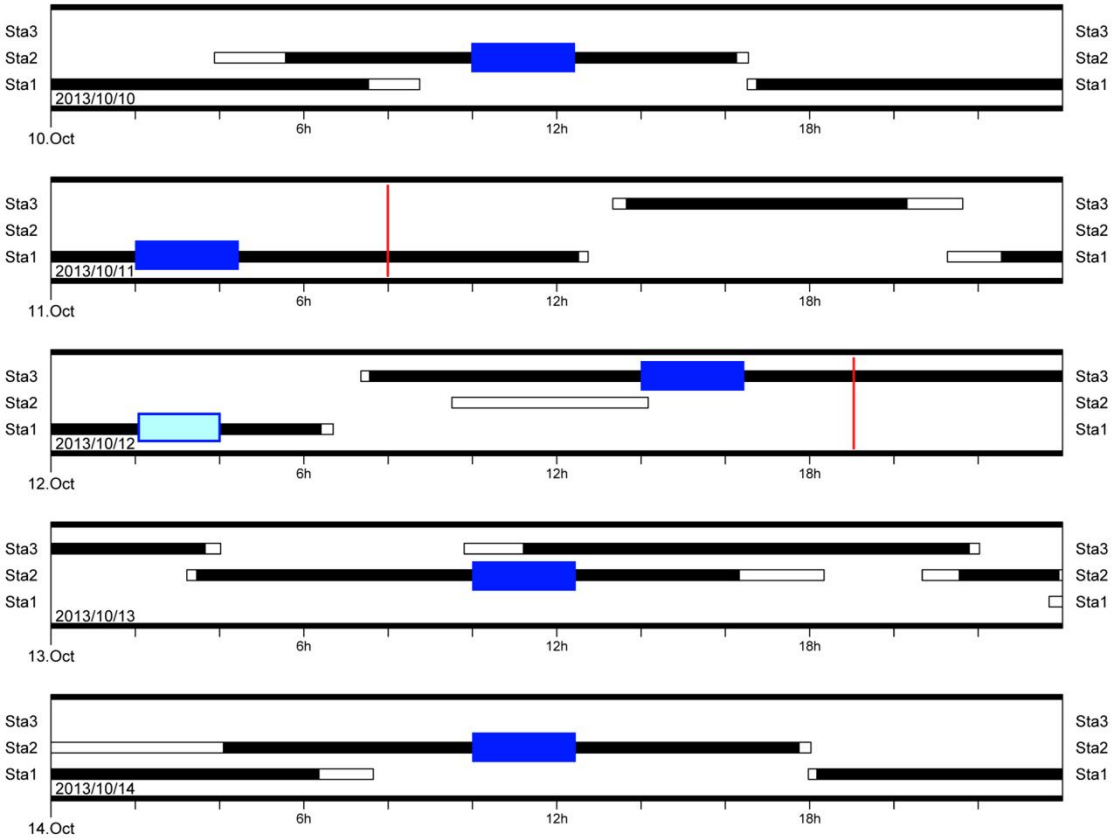
Retrieval of Satellite after Thruster Failure

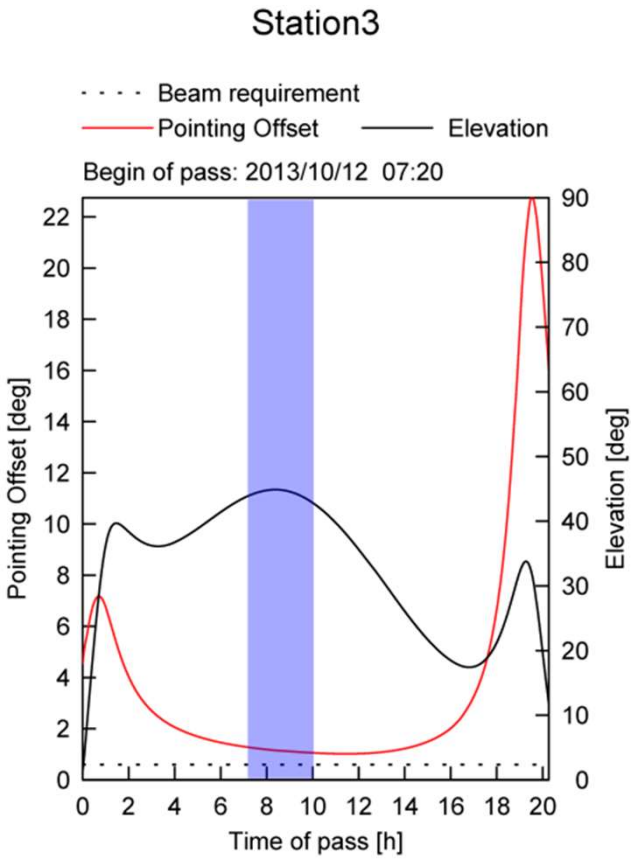




✓ Satellite still visible

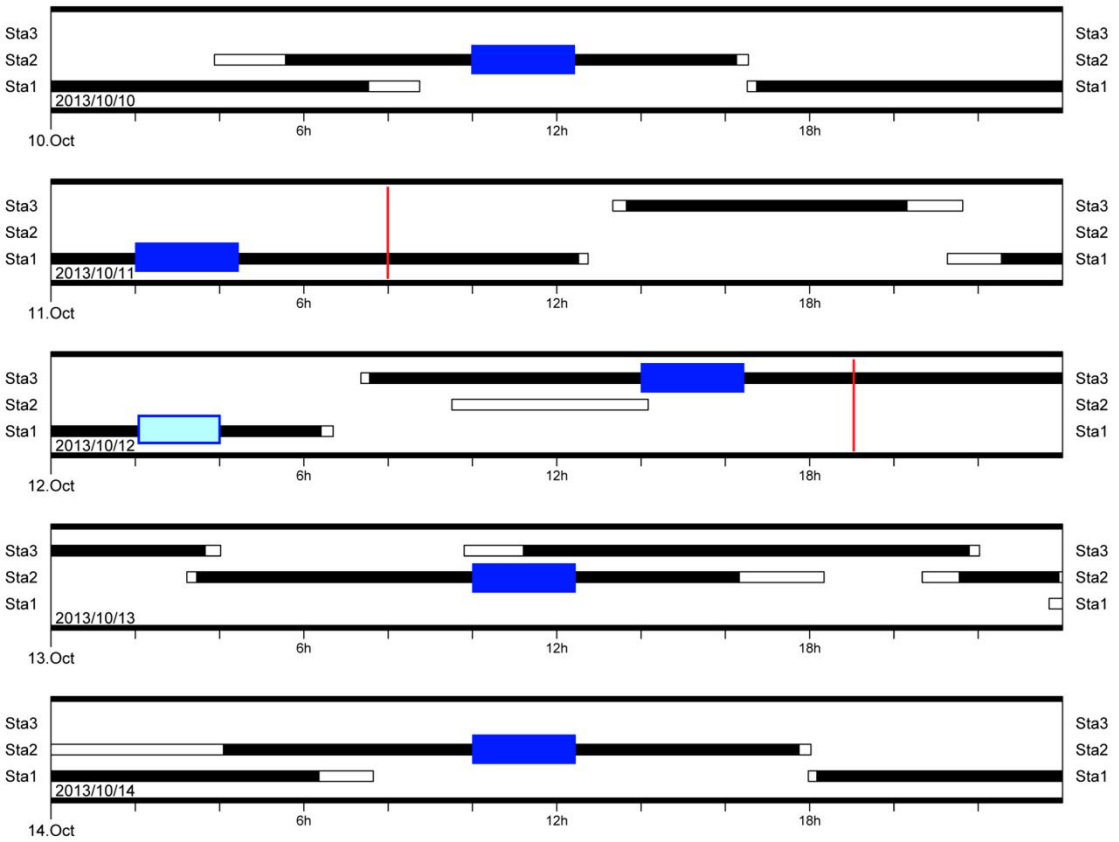
Retrieval of Satellite after Thruster Failure

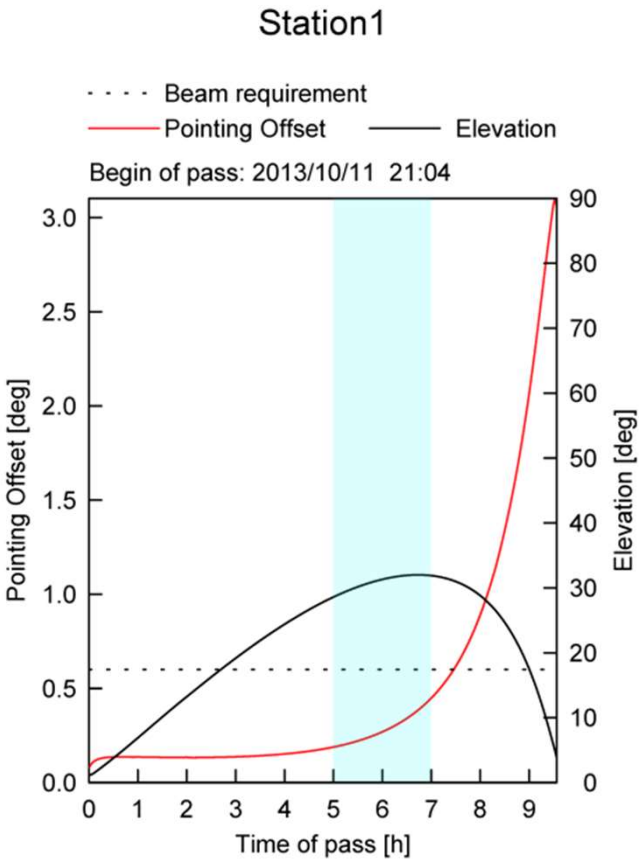




- Potential loss of satellite

Retrieval of Satellite after Thruster Failure





✓ 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!