Thermal Aspects of Long Term Operations on a Comet Surface

ESATAN
a simulation tool for experiment timeline optimisation

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Introduction

- Aim of Rosetta Lander:
  - In situ investigation of physical and chemical properties of a comet nucleus during the approach of the comet to the sun
    - Heliocentric distance: 3 to 1.x AU
    - Duration: about 6 months
    - Target: Comet 67P / Churyumov-Gerasimenko
    - Launch: Feb-2004
    - Landing: Nov-2014

Rosetta Lander on Comet Surface (artist's view – courtesy ESA)

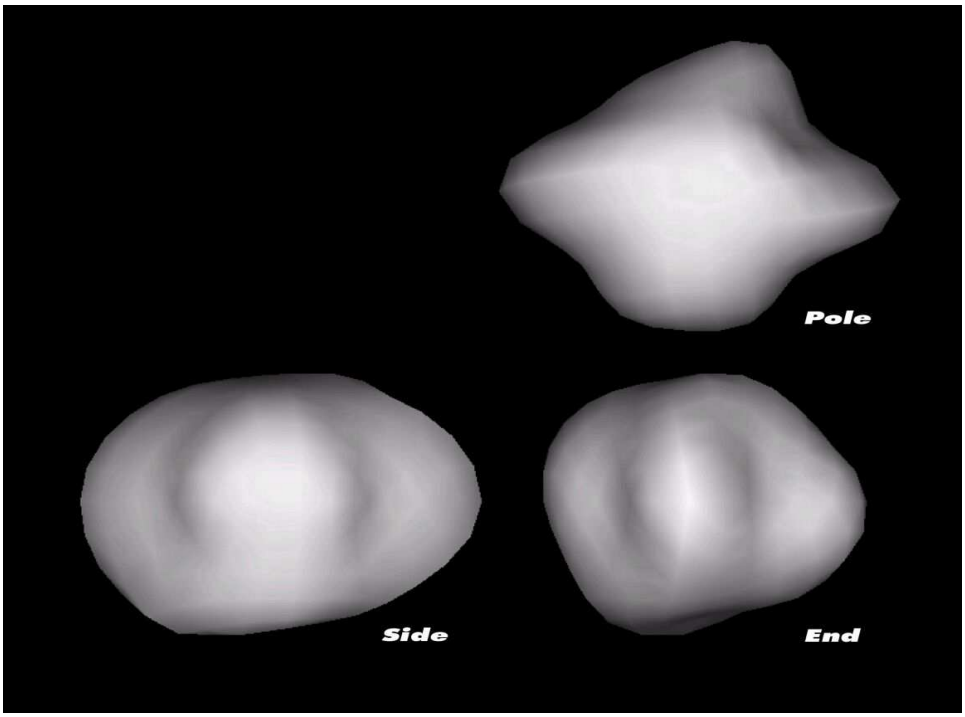
Fact Sheet

Comet 67P / Churyomov-Gerasimenko	
Perihelion	1.3 AU
Aphelion	5.7 AU
Orbital period	6.57 years
Radius of nucleus (evaluated from HST observation, March 2003) *)	1980 m
Rotational period (evaluated from HST observation, March 2003) *)	12.7 h
Albedo	0.04
Thermal emissivity	0.94

*) DPS (Division of Planetary Science) 35the Mtg, Sept 2003, Ames, Moffett Field, Cal

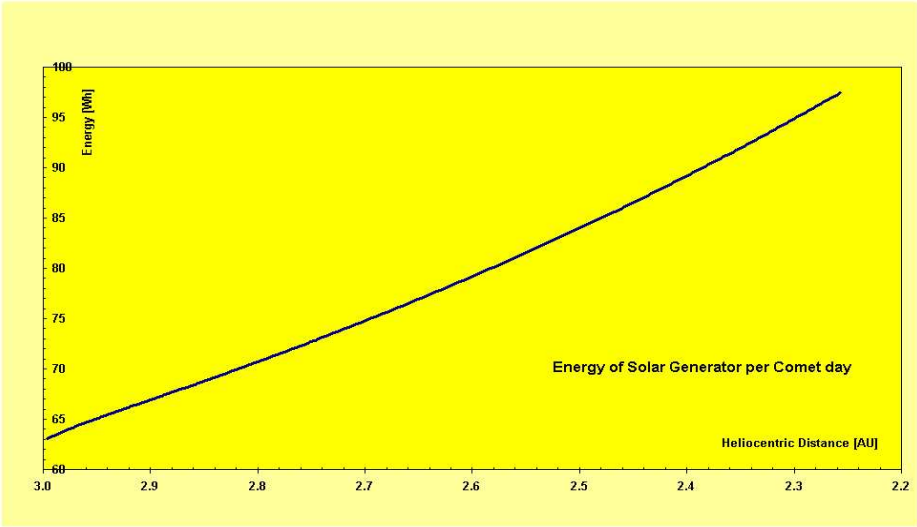
Nucleus of 67P / Churyumov-Gerasimenko

based on HST Observations



Courtesy ESA

- Problem:
  - Low energy availability for long term operations on comet surface



- Request:
  - About 9 W only for basic subsystems (power control, command and data management, telecom system) operations

- Conclusion:
  - Continuous operations impossible
- Consequences
  - Interruption of operations results in cooling down of Lander warm (electronics) compartment in particular during comet night
  - Wake-up and active temperature control requested, when power available again, before resuming operations
- Basic plan for long term operations
  - Phases of some days used for energy collection in sec battery followed by
  - Phases of experiment execution

- Thermal constraints
  - Lander operations possible, when compartment temperature above –45°C
  - Battery recharging possible, when battery temperature above Lower Limit of Charge (LLC = 0°C)
  - Battery discharging possible, when battery temperature above –30°C

➢ Thermal Control has a major impact on long term operations

Key Issues Thermal Control

- 3 independent control mechanisms
  - Hibernation Heater System
    - Activated by Orbiter during Lander and Orbiter hibernation in cruise phase
    - Hot redundant system
  - Thermal Control Unit
    - Active, when Lander is active
    - Cold redundant units for heater control and temperature monitoring
  - Wake-up Heater System in Combination with Power Enough Mode
    - Controlled by thermostat and Bus Voltage measurement
    - Active during cruise and on Comet, when Lander temperature below –47.5°C or electrical power not sufficient to operate Lander

Thermal Control Unit - TCU

- Operational Constraints
  - PSS and CDMS operating, i.e. about 6 W electrical power requested
  - Ops power request : about 130 mW per TCU unit (heater power excluded)
  - Main or/and redundant
- Tasks
  - Temperature monitoring (31 temperature sensors per TCU unit, most redundant)
  - Heating of compartment (6 individually controlled heater units per TCU unit, redundant)
  - Heater current monitoring

TCU continued

- Heater supply power (28V main bus) provided for each TCU on 3 lines for
  - Compartment heaters (4*2 W for each TCU)
  - Heater in primary battery (2.6 W for each TCU)
  - Heater in secondary battery (2.4 W for each TCU)
- Power is en/disabled by nominal CDMS/PSS ground TC
- Control of individual heaters is en/disabled by nominal TCS ground TC
- Heating control according set-point (nominal)
  - Common set-point for
    - Compartment heaters (Group A)
    - Battery heaters (Group B)
  - Set-point (–40°C default) may be updated individually for each group by nominal TCS ground TC

Wake-up Heater System
in Combination with Power Enough Mode

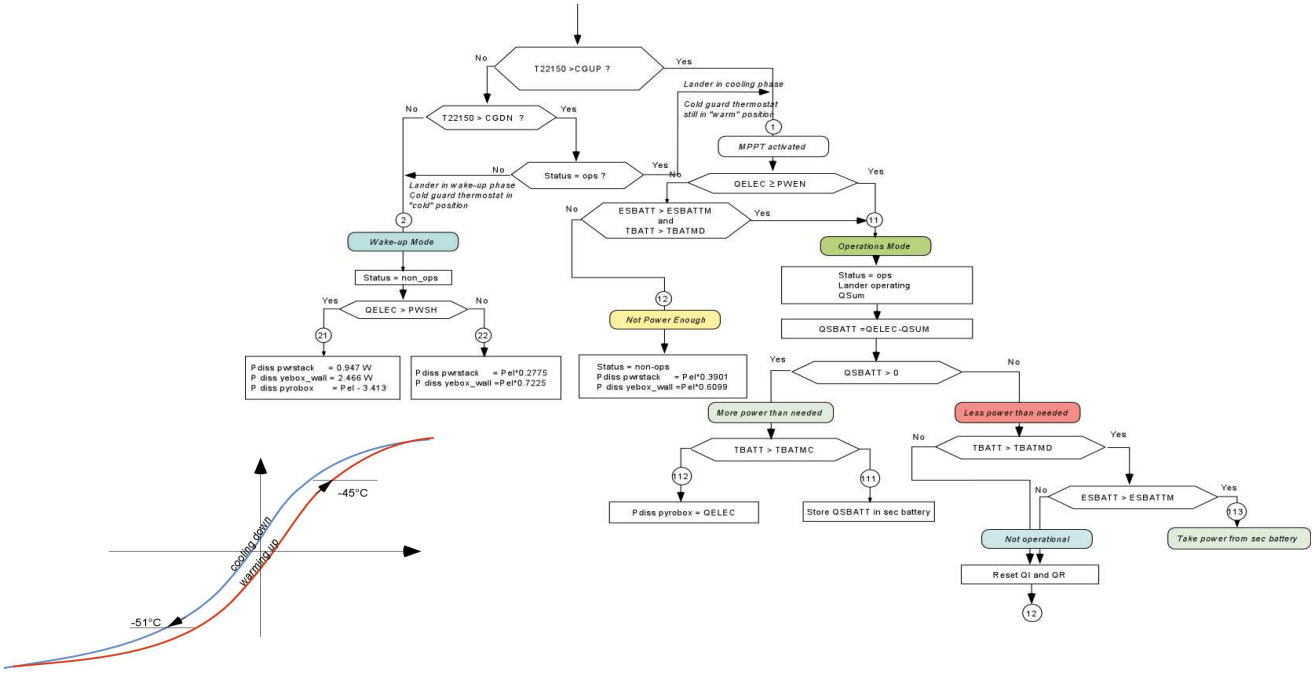
- Active when
  - temperature of PSS electronics below –45°C / -51°C

  or
  - Bus Voltage < 18.5 V
- Available Power
  - generated per solar generator (on comet)

  or
  - provided by Orbiter (during cruise)

  dissipated in „wake-up“ heater

Wake-up Heater System continued



Implementation into ESATAN Model

$INITIAL
Define Comet / Lander parameter
Rotation period
Co-ordinates of landing point
Local time of landing
Read: Start conditions
Actual time
Heliocentric distance
Actual energy in secondary battery
Temperature start vector

$EXECUTION

Define operations mode

CALL SLFRWD

$VARIABLES1
AU = AU(t)
Comet_surface_temperature= f(t)
Thermal_power_input(t)
Solar_generator_output(t,T)
Control operations
Lander operating QI=f(t)
hibernating/wake-up QR=f(t)
battery heating / no heating QR=f(t,T)
battery charge / discharge Qelec=f(T,P)
QI=f(T,P)

$VARIABLES2
Update energy content of secondary battery

$OUTPUT
Store /print AU,T,QI,QR,Qelec,E_sec_batt

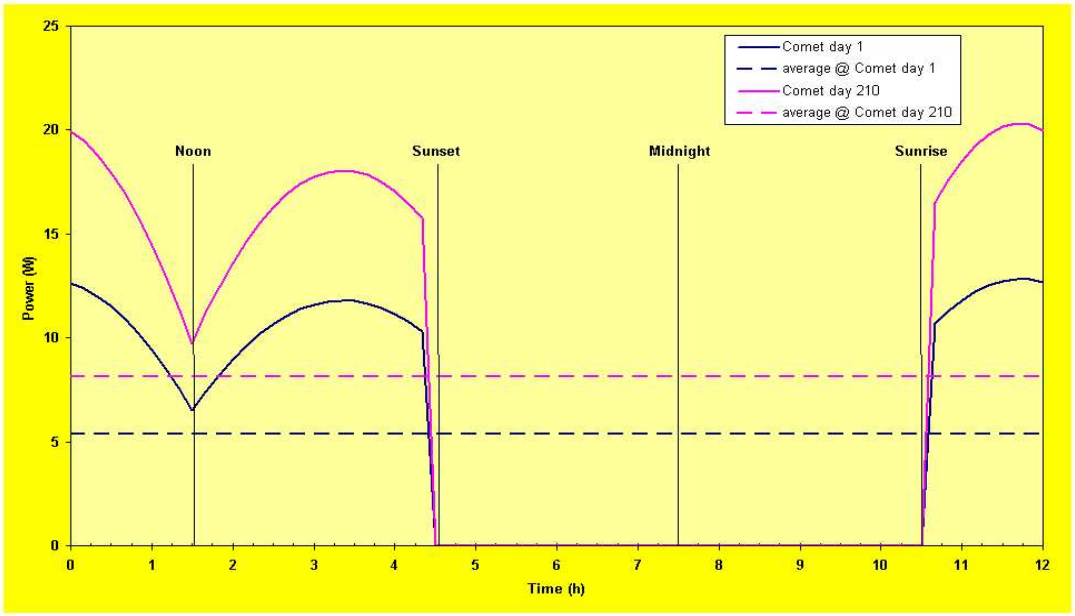
Thermal Analyses

- Long term operations
  - Start after completion of „First Science Sequence“
    - Started immediately after landing at
      - 3 AU
      - Near equator,
      - Lander Z-axis to Zenith
      - Lander X-axis to South
      - Landing time 4:30 (Comet time)
    - Duration 60 hrs
    - High power dissipation (power provided by primary battery)
    - Average compartment temperature at about 25°C
  - Primary battery exhausted
  - Operations rely on electrical power generated by solar generator, supported by secondary battery
  - Only basic subsystems (PSS, CDMS, Telecom in receiving mode) active
- Activated Thermal Control Units (only control of heater in secondary battery enabled) optional
  - Transient analyses executed for 210 Comet days (2520 h)

Thermal Analyses continued

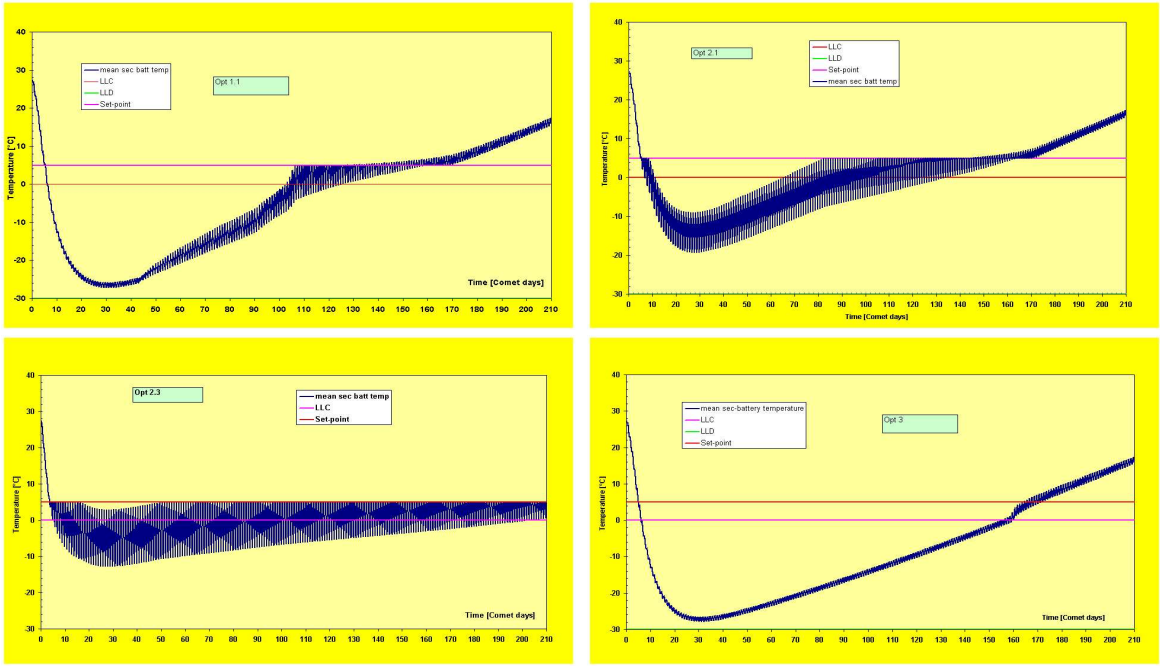
	PSS,CDMS Telecom	Both TCUs Heater in Sec Battery enabled	One TCU Heater in Sec Battery enabled	No TCU
1.1	continuously	continuously		
1.2	continuously	only during daytime		
2.1	continuously		continuously	
2.2	continuously		only during daytime	
2.3	only during daytime		only during daytime	
3	continuously			continuously

Expected Solar Generator Power

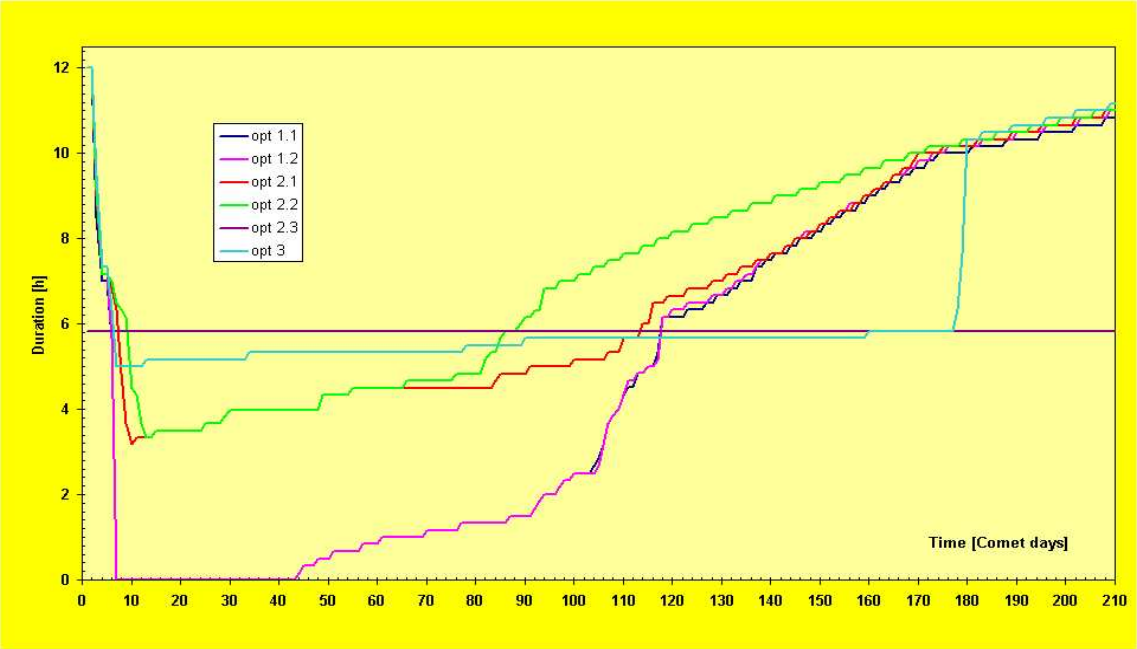


- In first order independent of operational option

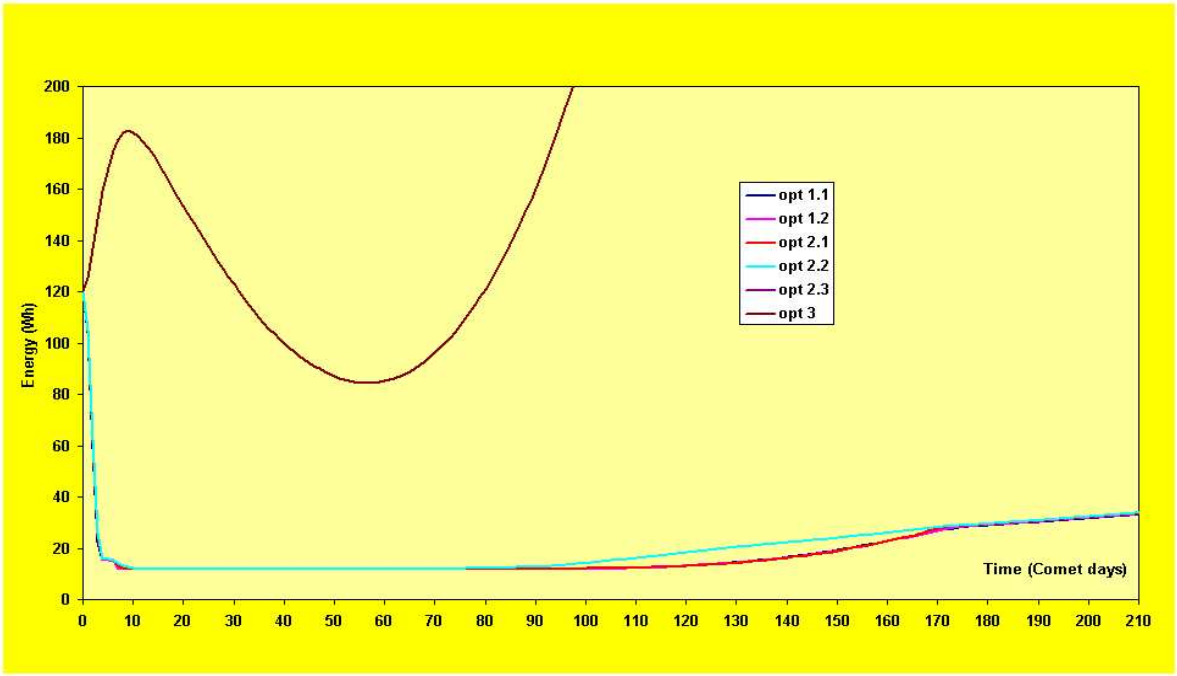
Temperature of secondary Battery



Duration of operational Phases
per Comet day



Energy Content in secondary Battery



Conclusions

- Rosetta Lander
  - On the basis of the analytical results the following recommendation for long term operations is derived
    - Schedule phases of energy collection followed by phases of experiment execution (high power consumption)
    - Inhibit night operations during phases of energy collection

- Thermal Analyser S/W
  - Esatan is an adequate tool to simulate thermal conditions of S/C operations
  - Esatan allows the implementation of relative complex operational constraints for transient analysis