# Re-Entry Simulation and Landing Area For YES2


**(2nd Young Engineers' Satellite)**

**www.YES2.info**

**Silvia Calzada (stagiaire ESA/ESTEC)**

UNIVERSITY of OULU

Delta UTEC

esa
www.YES2.info

# Thesis Objectives

- Development of **REST**
  **(Re-Entry Simulator Tool)**
- Investigations with **REST**
  Calculations of trajectory and landing area
- Conclusions
  1) To choose the best place to land
  2) Mission recommendations to minimize landing area

# Re-Entry Simulator Tool

The REST simulator includes many parameters:

- Inertial <-> Fix to Earth reference system
- Geodetic <-> Geocentric coordinates
- Rotational velocity of the Atmosphere
- Effect of the rotation of the Earth
- Bulge effect of the Earth
- Spherical harmonic expansion for the Earth's gravitational potential, J2 (zonal)
- Heat flux, temperature in the wall
- Drag coefficient for different regimens
- Flow regimen
- Density model NRLMSISE-00
- Wind model HWM-93
- G2S density, wind, gravity wave model
- Landing area (Monte Carlo Simulations)

# Re-Entry Simulator Tool

## The REST simulator includes

- Inertial <-> Fix to Earth reference system
- Geodetic <-> Geocentric coordinates
- Rotational velocity of the Atmosphere
- Effect of the rotation of the Earth
- Bulge effect of the Earth
- Spherical harmonic expansion for the Earth's gravitational potential, J2 (zonal)
- Heat flux, temperature in the wall
- Drag coefficient for different regimes
- Flow regime status
- Density model NRLMSISE-00
- Wind model HWM-93
- G2S atmospheric model with the latest meteorological conditions
- Landing area (Monte Carlo Simulations)

# REST

Re-Entry Simulator Tool REST v2.02sf2 for YES2, Delta-Utec 2003.

**Capsule**

| | |
|---|---|
| Mass [kg] | 8 |
| Surface [m^2] | 3 |
| L over D | 0 |
| Kn transition | 10 |
| Kn continuum | 0.01 |
| Critical Reynolds | 300000 |
| Volume [m^3] | 0.45 |

☐ Constant Cd

**Initial position**

| | |
|---|---|
| Inclination [deg] | 62.8 |
| Longitude [deg] | 4 |
| Latitude [deg] | 52 |
| Initial height [m] | 120000 |
| Solar local time [hr] | 0 |
| Day of the year | 136 |

**Initial velocity**

☑ Ascending

| | |
|---|---|
| Reentry angle [deg] | 1.5 |
| Initial velocity [m/s] | 7830 |

☐ Simple gravity
☐ Simple heat model
Attitude ☐

Emittance 0.8

**Heat model**

| | |
|---|---|
| Skin density [kg/m^2] | 3 |
| Typical capsule dim. [m] | 1 |
| Energy accom. factor | 0.95 |
| Radius nose [m] | 1 |

**Atmosphere**

Density
- ○ Simple
- ○ Standard US 1976
- ◉ MSISE00

☑ HWM93
☐ G2S atmospheric prediction

**Solar geomagnetic indices**

| | |
|---|---|
| Solar flux index | 150 |
| Solar flux index (81) | 150 |
| Geomagnetic index | 15 |

**Integrator**

| | |
|---|---|
| Endtime [s] | 10000 |
| Steptime [s] | 1 |

Load | Save

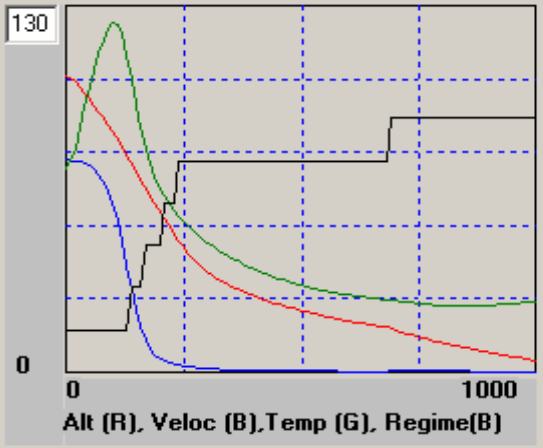
**Output file**

Note:

☑ New file 0245

Time interval output lines [s] 10

Start | Pause Time 10000




| | |
|---|---|
| 1.072E+003 | Time [s] |
| 2.599E+001 | Air velocity [m/s] |
| 8.077E-002 | Mach |
| 2.512E+002 | Temp wall [K] |
| 6.119E+004 | Total pressure [Pa] |
| 2.782E+002 | Dyn. pres. [Pa] |
| 6.508E-001 | Diss. power [kW/m^2] |
| 1.006E+000 | Accel. [gee] |
| 2.577E+002 | Temp atm [K] |
| 8.234E-001 | Density [kg/m^3] |
| 2.360E+001 | Longitude [deg] |
| 5.976E+001 | Latitude [deg] |
| 4.005E+000 | Altitude [km] |
| Subs.SupCr | Regime |

**Max Condition**

- ○ Temperature
- ○ Dissipated power
- ○ Dynamic pressure
- ○ Acceleration
- ◉ Landing

**Flow regime**

Hypersonic | Supersonic | Transonic | Subsonic

Continuum flow 1071

## Monte Carlo Standard Deviations (1 sigma) Pretimely stop!

**Vehicle**

| | |
|---|---|
| Re-entry angle [deg] | 0 |
| Initial velocity [m/s] | 0 |
| Cd | 0.05 |
| L over D | 0.01 |

**Above 90 km**

| | |
|---|---|
| Density [-] | 0.2 |
| Meridian wind [m/s] | 20 |
| Zonal wind [m/s] | 22.7 |

**Between 90 to 60 km**

| | |
|---|---|
| Density [-] | 0.15 |
| Meridian wind [m/s] | 9.3 |
| Zonal wind [m/s] | 12.8 |

**Below 60 km**

| | |
|---|---|
| Density [-] | 0.15 |
| Wind velocity [m/s] | 20 |
| Wind angle [deg] | 15 |

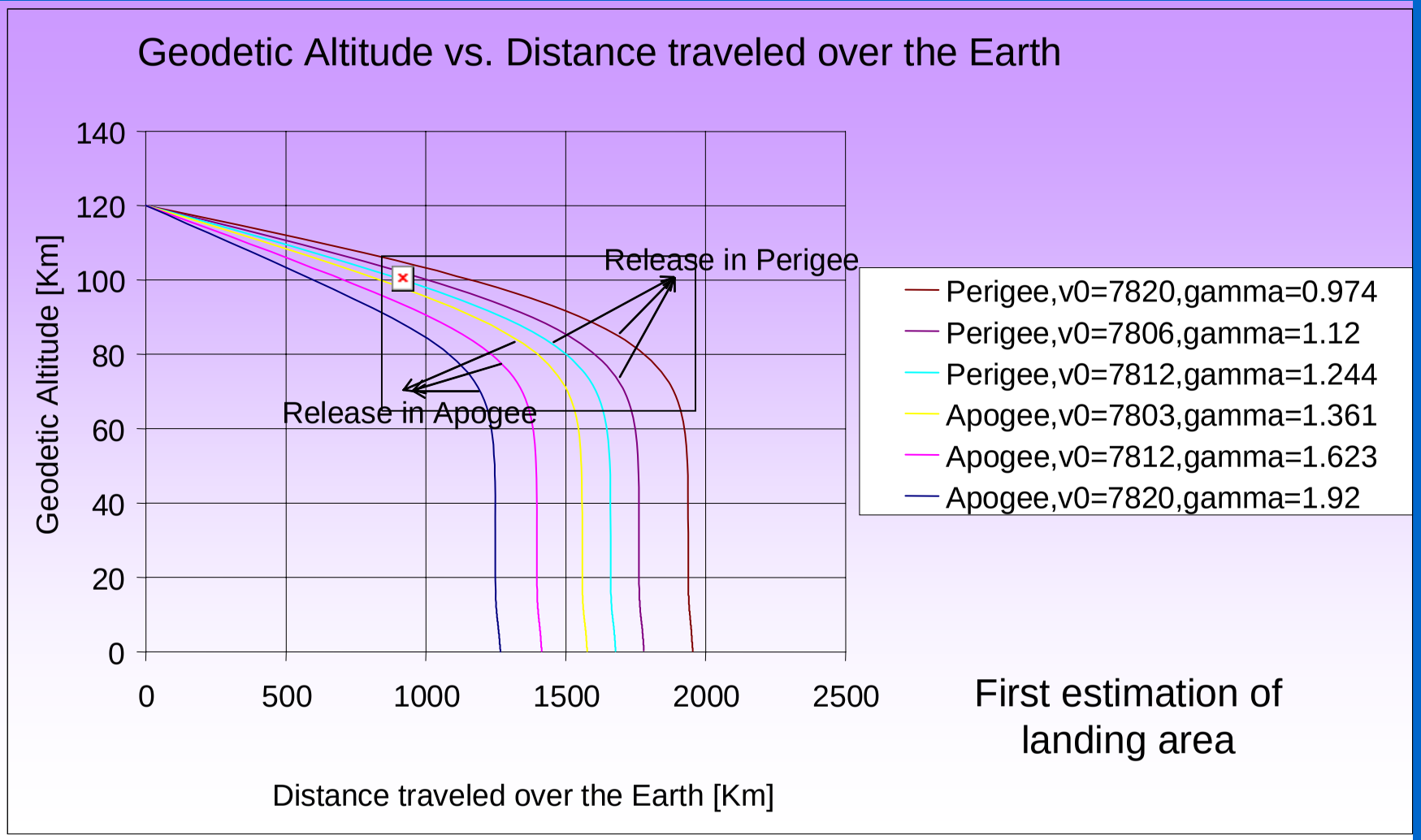
☐ Known weather conditions

Monte Carlo Landing Area

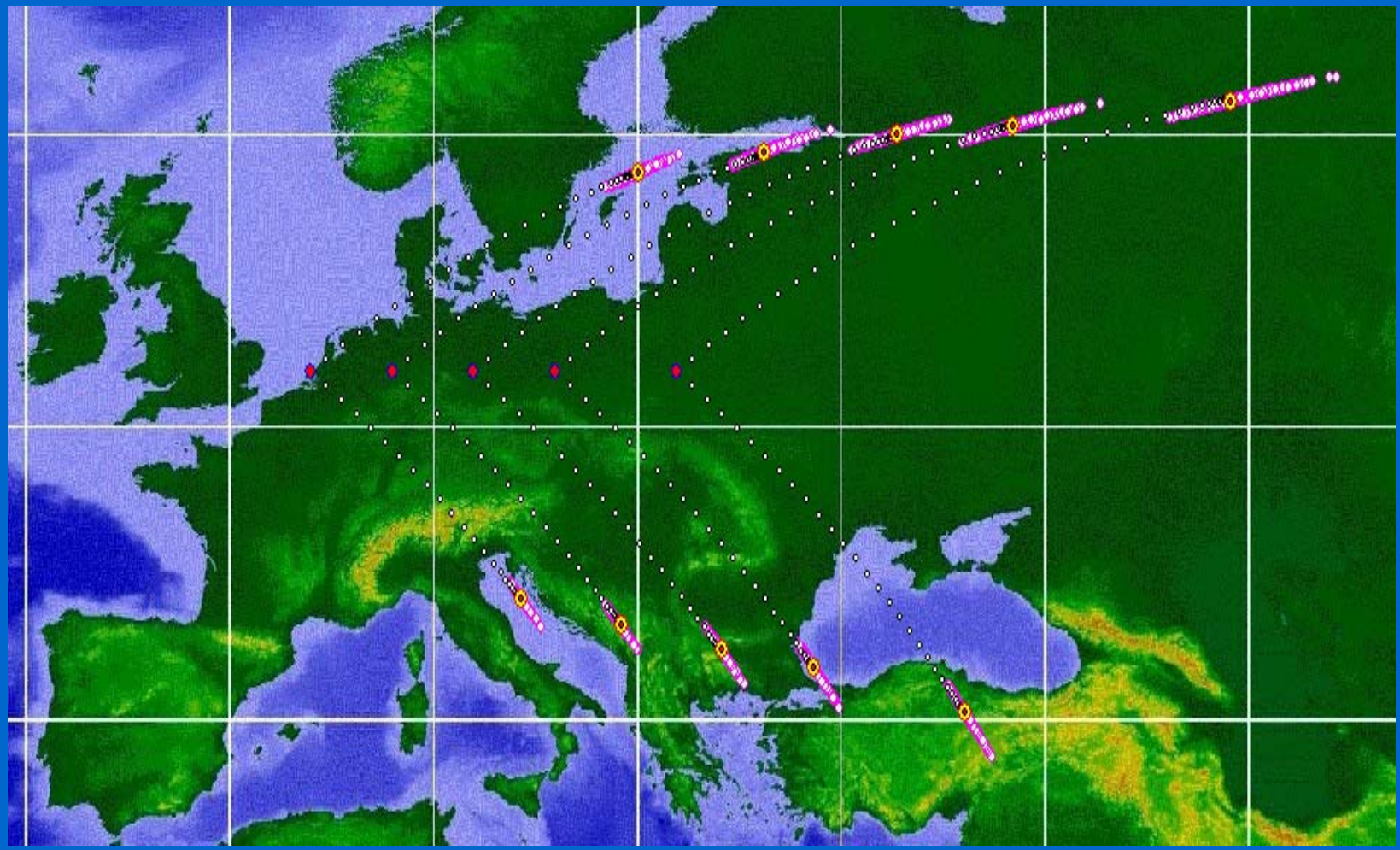
0 | # MC runs 100

Show Map

# Altitude vs. Distance



# Landing Area Depending On Re-Entry Conditions $v_0$ and $\gamma$



# Re-Entry Concerns

1) Heat flux & Temperature in the wall

2) Supercritical Reynolds number
Turbulence flow in subsonic flow regime

3) Because low ballistic coefficient of the capsule, the peak of the:
wall's temperature,
heat flux,
dissipated power,
gee-load
are happening in the upper part of the re-entry
(transition from rarefied gas and continuum flow regime)

# Mission recommendations to minimize landing area

Orbit: highest apogee, lowest perigee (largest length of tether)
Tether cut time in apogee and descending part of the orbit
Steepest entry angle
Optimal entry time: 00:00-03:00 am
Optimal day: around 21th June
Knowledge weather conditions
Heavy capsule