ALTAN application to Bepi-Colombo thermal analysis

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• The Bepi-Colombo mission to Mercury consists of at least two orbiters, the Mercury Magnetospheric Orbiter (MMO) and the Mercury Planetary Orbiter, a lander was also considered.
• In Mercury orbit the solar constant is from 4.5 to 9 times that on Earth, the albedo alone may correspond to a solar constant on Earth, the infrared emission of the planet is up to 10000 [W/m2]. The illuminated side of the planet may reach 700 [K], while the dark side remains at about 100 [K].
• This scenario is not easily modelled with the available radiative software, as ESARAD, THERMICA, TRASYS, THERMAL DESKTOP.
• Scope of this presentation is to identify the limits of the present thermal software, and to present a thermal software developed in ALENIA which overcomes these limits.

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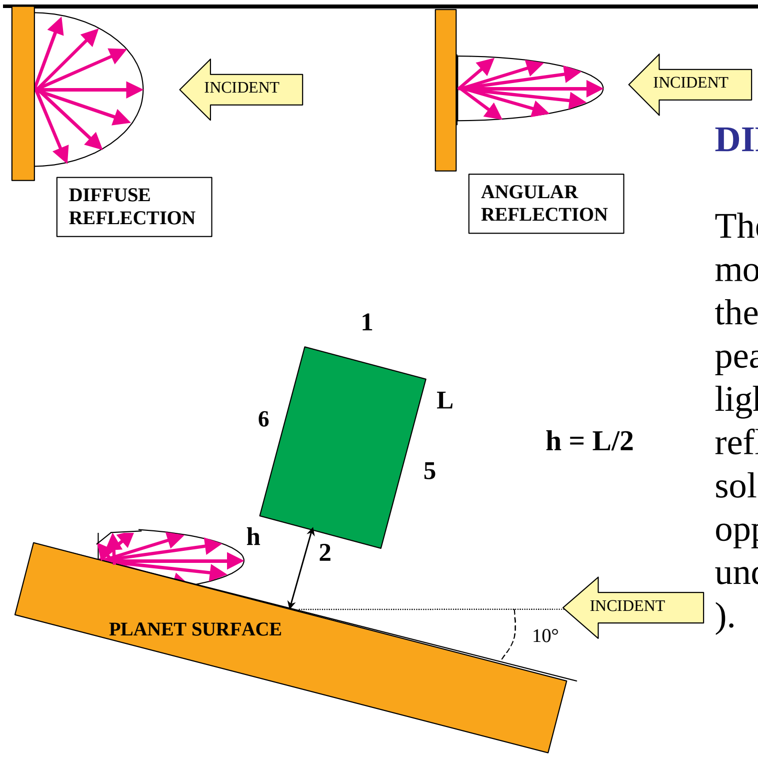

DIRECTIONAL REFLECTIVITY

The radiative software in not able to model the directional reflectivity of the planet surface, which presents a peak in the direction of the incident light; the software assumes diffuse reflectivity, as a consequence the solar fluxes reflected on surfaces opposed to the sun are underestimated (typically **30 – 50 %**).

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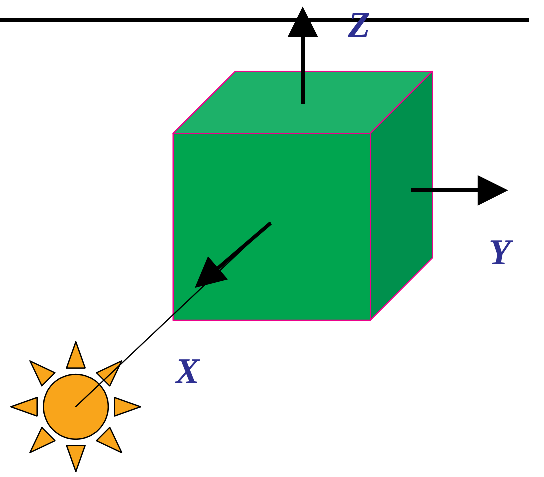
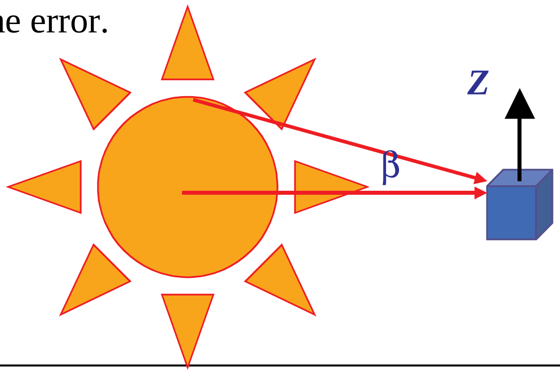
SUN DIMENSIONS

The sun is modelled as a point, while it has finite apparent dimensions: in earth orbit, the sun has a half angle β = 0.26°, in Mercury orbit at perihelion it is 0.87°; as a consequence, the solar fluxes at the poles are underestimated by the radiative software, and in general the fluxes on all surfaces of an Orbiter may be affected by some error.



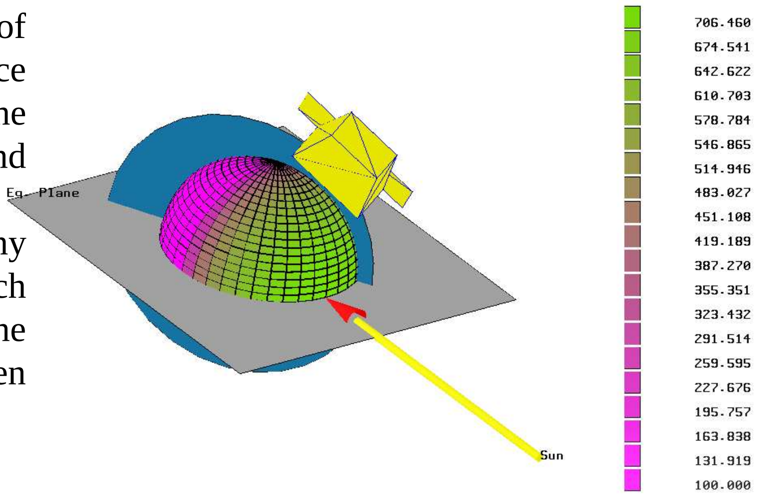


Perihelion:
β=atan(0.696/46.) = 0.87°
Average angle βave = 0.36°
Incident flux on +Z side:
*(14500/2)*sin(0.36°) =46 [W/m2]*
Calculated by radiative s/w = 0 [W/m2]

PLANET TEMPERATURE

The planet in the available thermal software is modelled as a sphere at uniform temperature. In the case of planet without athmosphere, the surface temperature and consequently the emitted energy vary with latitude and longitude.

As a consequence, the IR fluxes on any surface of a S/C depend on which portion of the planet is seen by the satellite surface. IR fluxes are then extremely variable during an orbit.



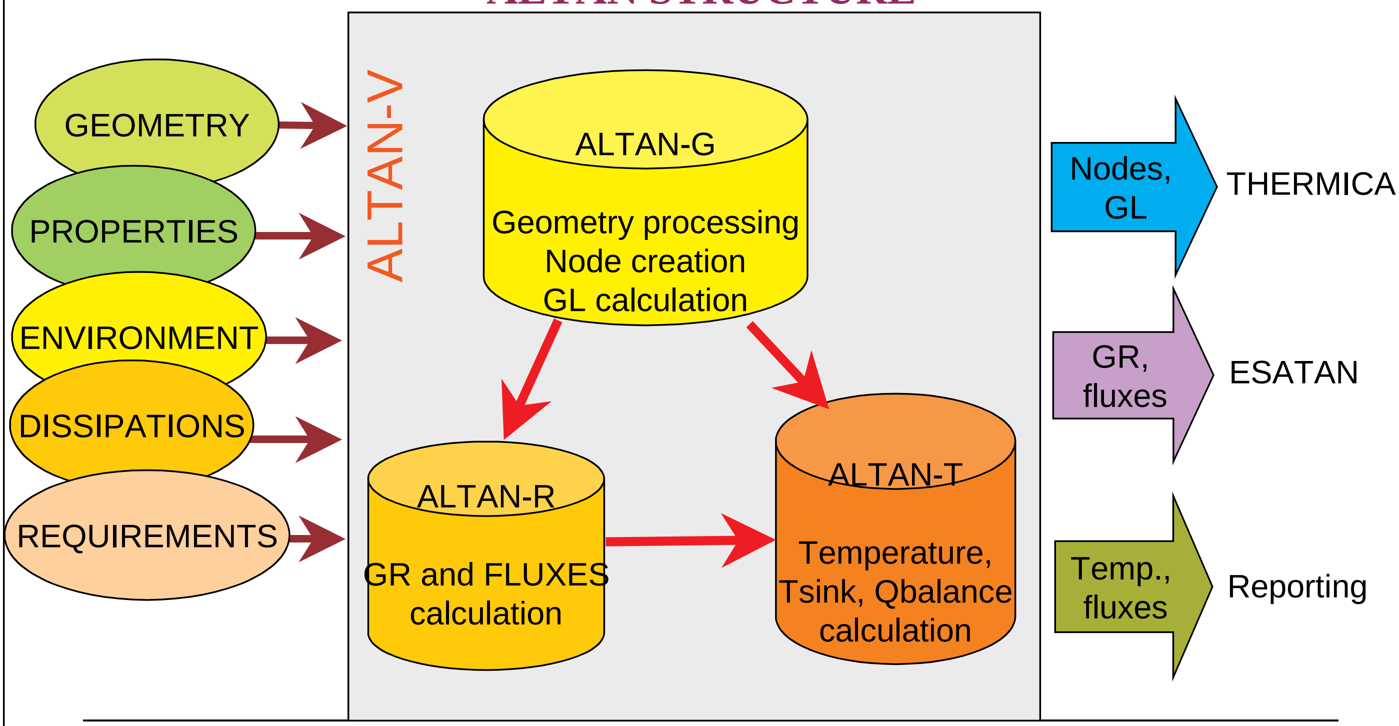
	IMPACT ON BEPI-COLOMBO THERMAL SIMULATION	SEVERITY
Planet directional reflectivity	Both the orbiters and the lander are affected. However the orbiters may benefit from the transient conditions, albedo from planet may be underestimated by the software when flying over the subsolar point, but may be overestimated in other orbital positions. In the case of a lander, the error depends on the configuration, i.e. radiator position. Several missions have flown on planets with such type of surface (Mars, the Moon), but on Mercury all thermal problems are amplified by the proximity with the sun.	3
Sun dimensions	All elements are affected, both the orbiters and the lander. Some Bepi-Colombo elements may have surfaces where the sunlight incidence angle is virtually zero. Design solution is to add some small shield to protect them.	2
Planet temperature	The orbiters are affected. Impact on the thermal design is important, additional uncertainty if planet temperature is not modelled accurately.	1

ALTAN REQUIREMENTS

To overcome the limits of the available radiative S/W, ALS has developed ALTAN, with these main requirements:

- GR calculated with ray-tracing technique;
- Simulation of directional optical properties;
- Non-uniform planet temperature;
- Two degrees of freedom for pointing;
- Complex geometries and limited boolean operations;
- GL calculation;
- Temperature calculation;
- Pre/post processing;
- Graphical User Interface;
- Interface with other thermal software;
- Runs on PC
- Based on Visual Fortran + Open GL

ALTAN STRUCTURE



ALTAN BASIC INPUT DATA

CONFIGURATION : identifies a set of thermal elements and associate them with data to locate them, to create nodes, to apply dissipations and requirements.

THERMAL PRIMITIVES (ELEMENTS) : identify a thermal / structural components defined by a geometry and properties (thermal / mass).

GEOMETRICAL PRIMITIVES: identify the geometry of a thermal primitive. They describe a SOLID, with extension and thickness. A geometrical primitive is described by:
•Shape (e.g. flat, cylinder, sphere…)
•Contour (limits to the extension defined in a local surface cordinate system)
•Holes (holes through the thickness defined in a local surface cordinate system)

THERMAL & GEOMETRICAL PRIMITIVES

GEOMETRICAL PRIMITIVE	THERMAL ELEMENT						
	RADIATOR	EQUIPMENT		MLI	DOUBLER	HEAT PIPE	TUBE
		Cover	Base				
polygon	X	X	X	X	X		
disk	X	X	X	X	X		
cylinder	X	X		X	X		
cone	X	X		X	X		
sphere	X	X		X	X		
paraboloid	X	X		X	X		
revol1	X			X	X		
revol2	X			X	X		
extruded	X			X	X	X	X

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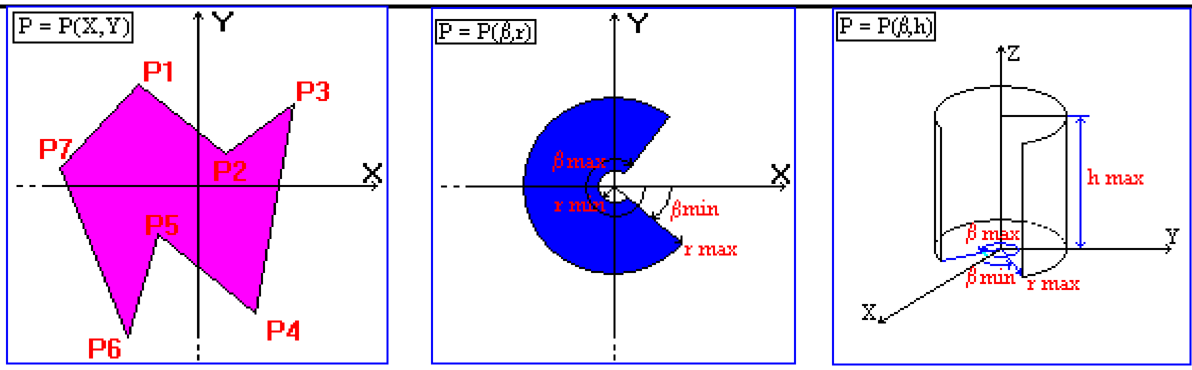
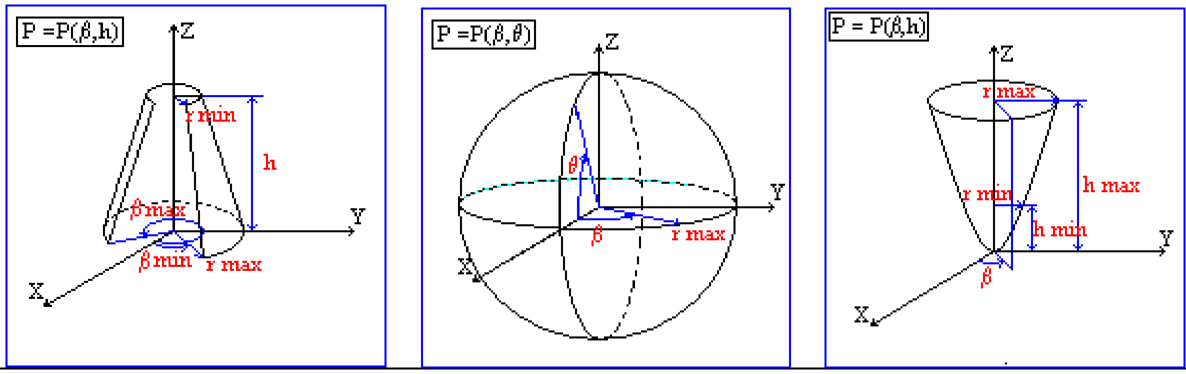


GEOMETRICAL PRIMITIVES



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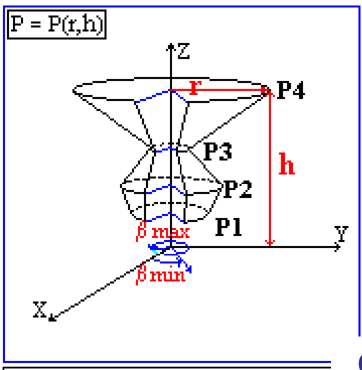
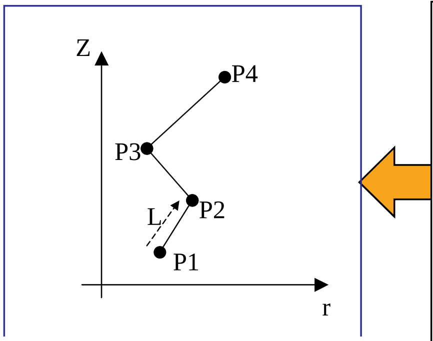




Revol1, Revol2 Define:

- A curve **C** of N points in a local ref. (r,Z)
- β_{min}, β_{max} (Revol1) or **N** steps (Revol2)

Revol1 is defined by rotating **C**, generating portions of disk, cylinder and cones

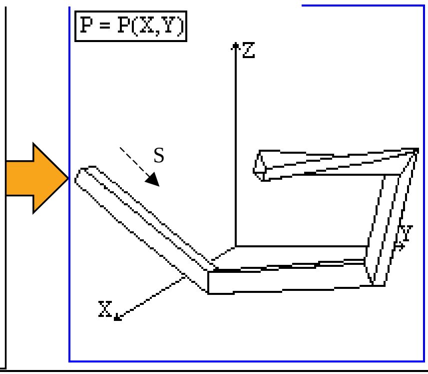
Revol2 is defined by rotating **C** by **N** steps and by joining the vertices of the resulting curves, generating flat surfaces (pyramid…)

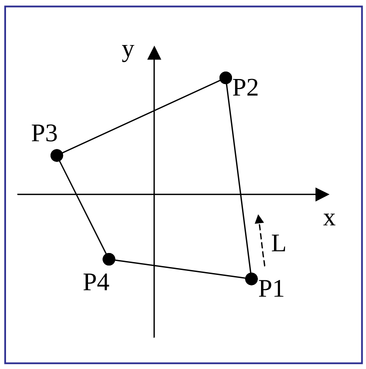
GEOMETRICAL PRIMITIVES

Extruded Define:

- A curve **C** of N points in a local ref. (x,y)
- A line **S** of M punti in (x,y,z)
- A vector ***V*** nello spazio (x,y,z) for each point M

The surface is defined by transporting the curve **C** along the line **S**, and by rotating **C** to keep its local x parallel to ***V***





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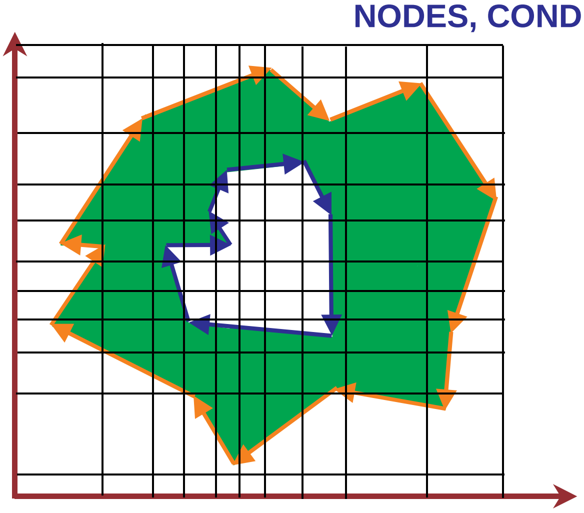
NODES, CONDUCTORS & TEMPERATURES



Nodes are generated by applying a grid to the geometrical primitive

GL are calculated by extension of typical formula K*area/distance

GR and orbital fluxes are calculated with MonteCarlo ray tracing.

Temperatures for steady state and transient are calculated by traditional methods (as ESATAN routines SOLVIT and SLFWBK)

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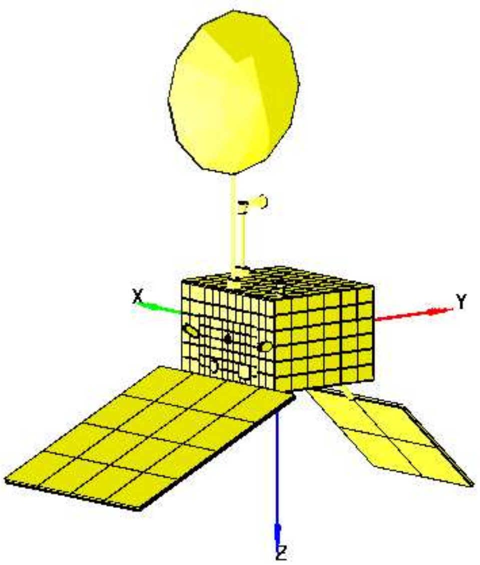
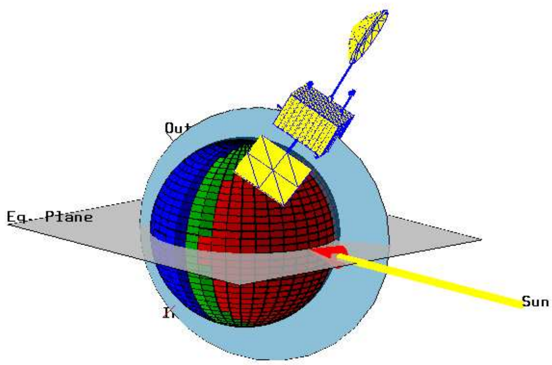
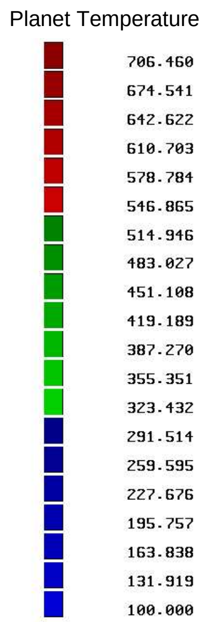
VISUALIZATION







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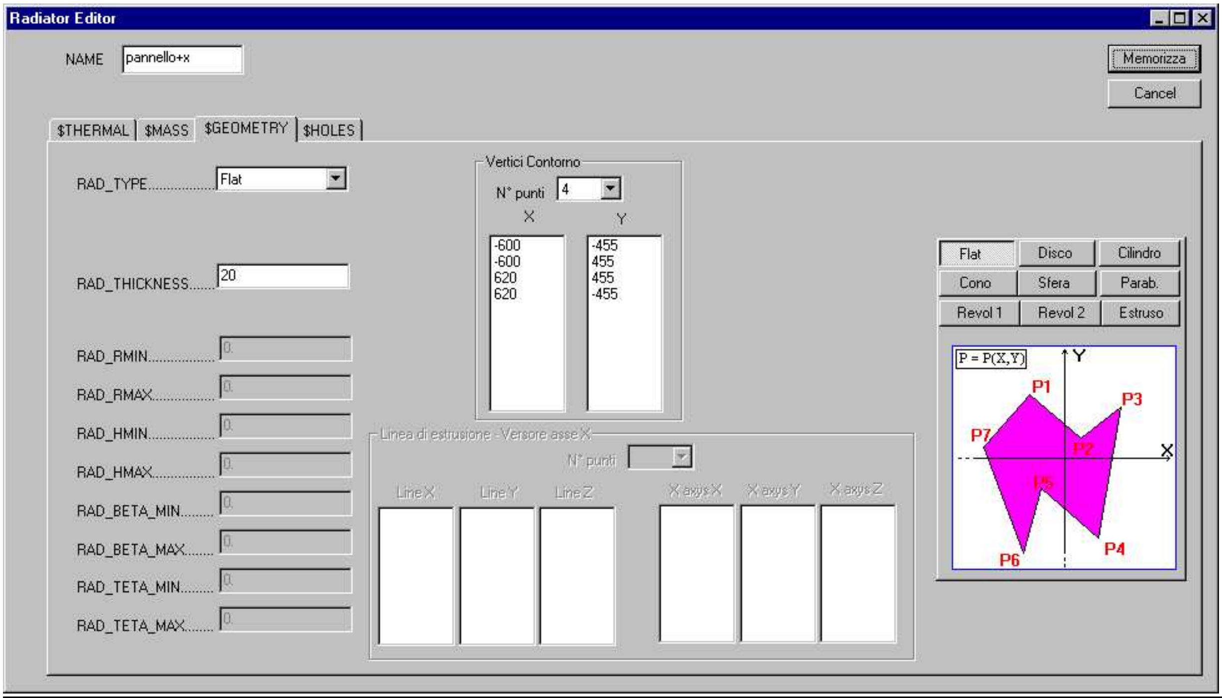
USER INTERFACE



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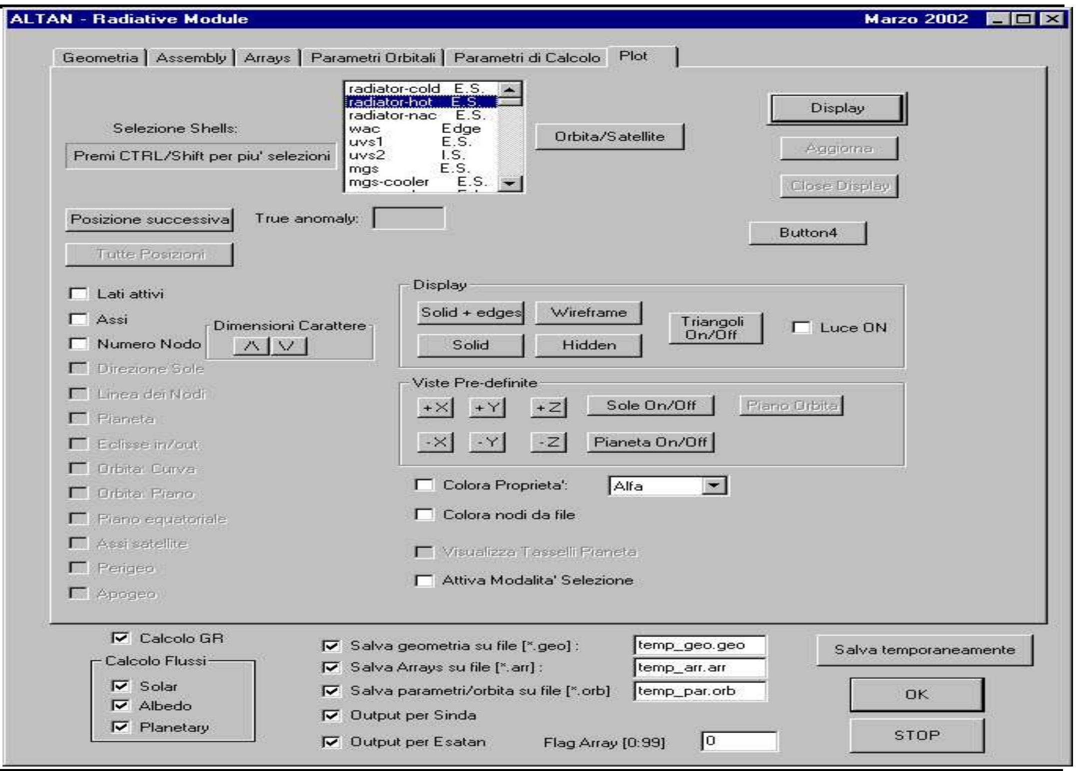

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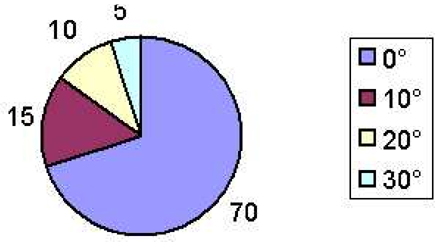
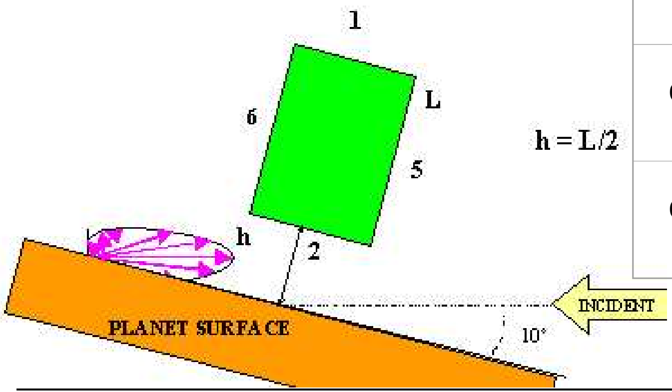
PLANET SURFACE ANGULAR REFLECTIVITY





Planet reflection & radiative S/W	INCIDENT SOLAR FLUX [W]					
	side 1	side 2	side 3	side 4	Side 5	side 6
Diffusive (THERMICA)	1692	329	114	115	9706	128
Diffusive (ALTAN)	1691	332	113	113	9703	127
Angular (ALTAN)	1692	72	20	21	9685	161

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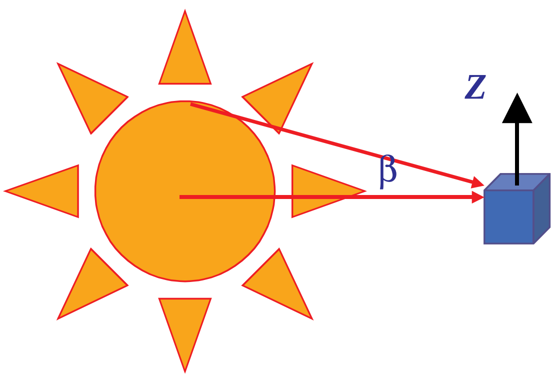
SUN DIMENSIONS



Radiative S/W	INCIDENT SOLAR FLUX [W]	
	+Z	+X
THERMICA	0	14383
ESARAD	0	14383
TRASYS	46	14387
ALTAN	47	14381

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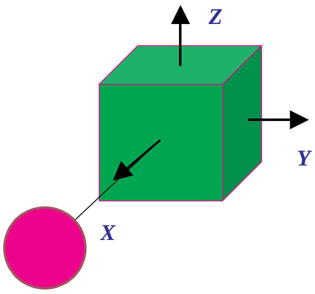
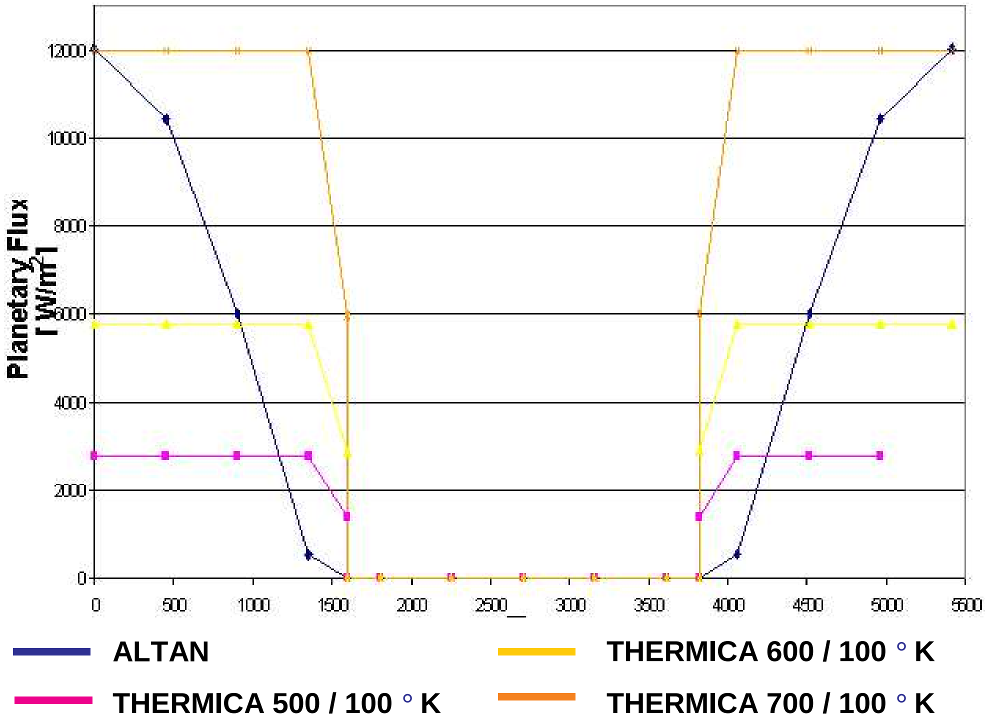
PLANET TEMPERATURE





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CONCLUSIONS

MISSIONS AS LEDA-LUNISS AND BEPI-COLOMBO HAVE REVEALED THE LIMITS OF THE COMMERCIAL RADIATIVE THERMAL S/W;

REQUESTS TO IMPROVE COMMERCIAL RADIATIVE S/W HAVE BEEN FREQUENTLY RAISED IN THE PAST YEARS BUT PROGRESS HAS BEEN INSUFFICIENT;

IN-HOUSE DEVELOPED S/W HAS BEEN NECESSARY, DRAWBACKS: COSTS, PROLIFERATION OF TOOLS, LOSS OF COMMON BASE;

SUGGESTION:
IMPROVEMENT OF COMMERCIAL S/W;
SUPPORT DEVELOPMENT OF INTERFACES TO STEP;