Europa Jupiter System Mission (EJSM)

Sub-Surface Radar for the Jupiter Ganymede Orbiter

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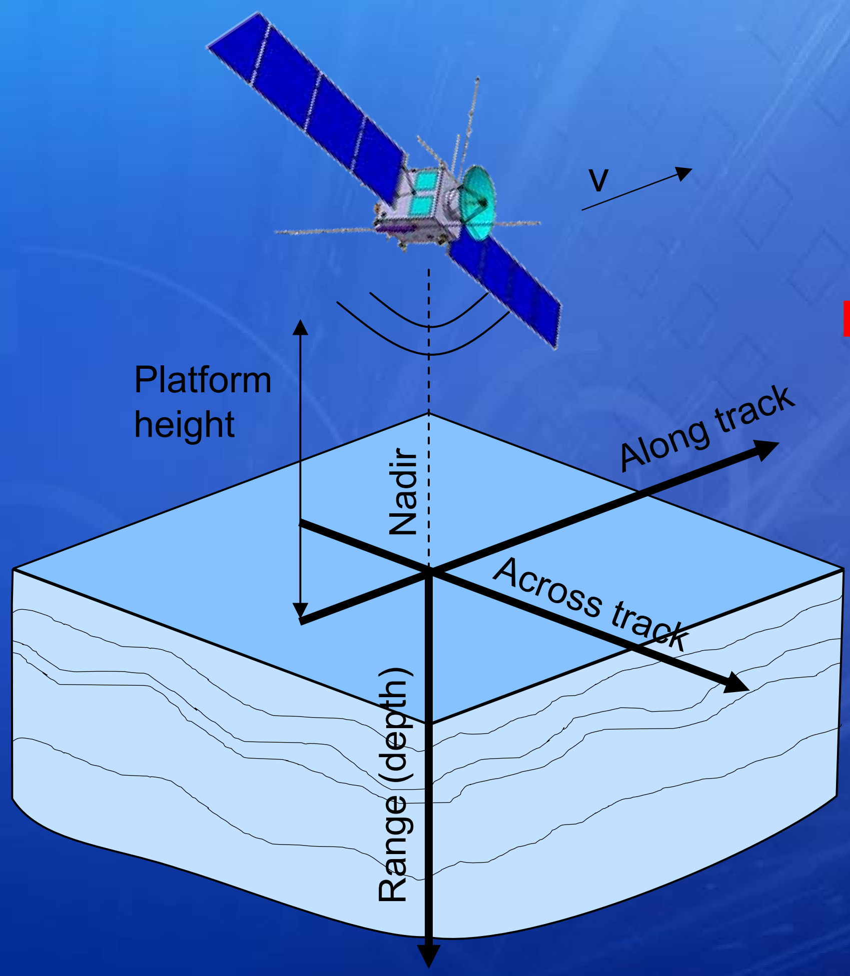
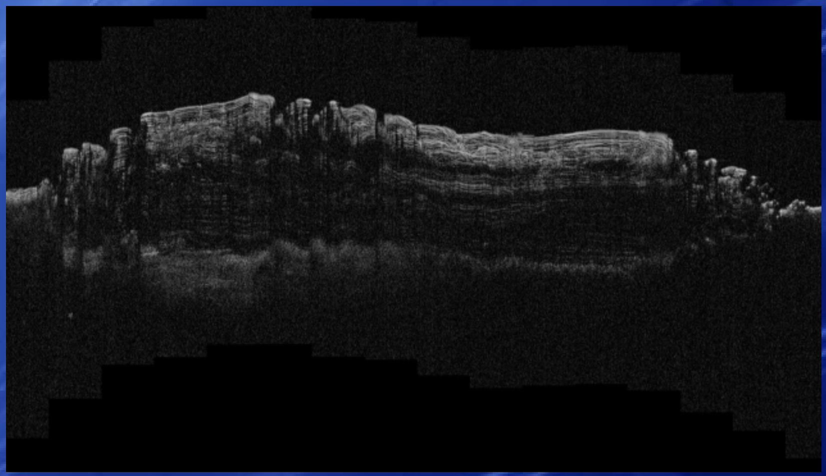
Sub-Surface Radar



Example of radargram
(SHARAD, 1069002)



Heritage: MARSIS (ESA MARS express), SHARAD (NASA Mars Reconnaissance Orbiter)

Main Scientific Goals

- Identification of the stratigraphic and structural patterns.
- Study of crustal behavior.
- Matching the surface geology with subsurface features and processes (tectonism, convection, etc.).
- Geology of Ganymede and its evolution.
- Location and characterization of water reservoirs.
- Comparison between Ganymede and Europa (and Callisto).
- Altimetry at moderate resolution.

Organization of the Study

Modeling and Simulation

- Surface and subsurface modeling
- Estimation of the Jupiter's radio emission
- Numerical model of the radar response
- Definition of instrument parameters to achieve science objectives

Instrument characteristics

- Instrument basic architecture (mass and power, data rate/volume)
- Performance evaluation
- Antenna definition
- Instrument interfaces

Acquisition strategy and synergies

- Acquisition strategy definition
- Synergies between JGO and JEO radars
- Synergies with other instruments on board JGO and JEO

Data processing

- Data processing requirements
- Definition of data analysis procedure

Environment issues

- Approaches for reducing radiation impact
- Planetary protection

WBS

- **Radar Sounder** UNITN
  - **Management** UNITN
  - **Mission** UNITN
    - **Acquisition strategy** **UNITN** – IFSI
    - **Synergy with other instruments** **LPG** – UNITN – IFSI
    - **Radiation effect & planetary protection** **TASI** – CORISTA
  - **Science** IFSI
    - **Revision of science objectives** **IRSPS** – IFSI – LPG – UNIPG – UNITN
    - **Surface and subsurface modeling** **LPG** – INFOCOM – CORISTA
    - **Noise analysis** **IFSI** – LPG – CORISTA
    - **Definition of instrument requirements** **IFSI** – IRSPS – LPG – UNIPG – INFOCOM – UNITN
  - **Instrument** CORISTA
    - **Architecture definition** **CORISTA** – INFOCOM – TASI – UNITN
    - **Antenna** **TASI** – INFOCOM
    - **Performance evaluation** **CORISTA** – INFOCOM – UNITN
    - **Data processing and analysis** **UNITN** – CORISTA – INFOCOM – LPG

Main Requirements

Orbiter altitude	200 km (in the circular phase around Ganymede)
Transmitted central frequency	In the range 20-50 MHz
Transmitted bandwidth	10 MHz
Antenna type	Dipole
Antenna size	< 10 m
Power	20 W (average)
Along track resolution	< 1 Km
Across track resolution	< 10 Km
Penetration depth	< 5 Km
Vertical resolution	15 m (vacuum)
Data rate	300 Kbps
Mass (without antenna)	10 Kg
Size	37×25×13 cm
Pointing requirements	Yaw steering possible, pitch acceptable but with possible degradation of performance

Pointing Issues

- **Yaw steering**
  - ✓ Does not affect the performance of a radar sounder in a measurable way;
  - ✓ No special requirements on the maximum allowed angular speed of the S/C during observations;
  - ✓ Any orientation of the dipole antenna is acceptable (along track, across track or 45°)

- **Pitch**
  - ✓ Antenna pattern may significantly deviate from that of a dipole because of the interaction between the emitted radiation and conducting spacecraft appendages;
  - ✓ Pitch is acceptable but very likely at the cost of degraded performance.

Models of Ganymede

- Development of models of the composition, structure, and roughness expected in the surface and subsurface:
  - ✓ Assessment of the radar penetration into Ganymede surface (and Callisto during flybys);
  - ✓ Definition of radar parameters;
  - ✓ Definition of signal processing (e.g. clutter reduction).

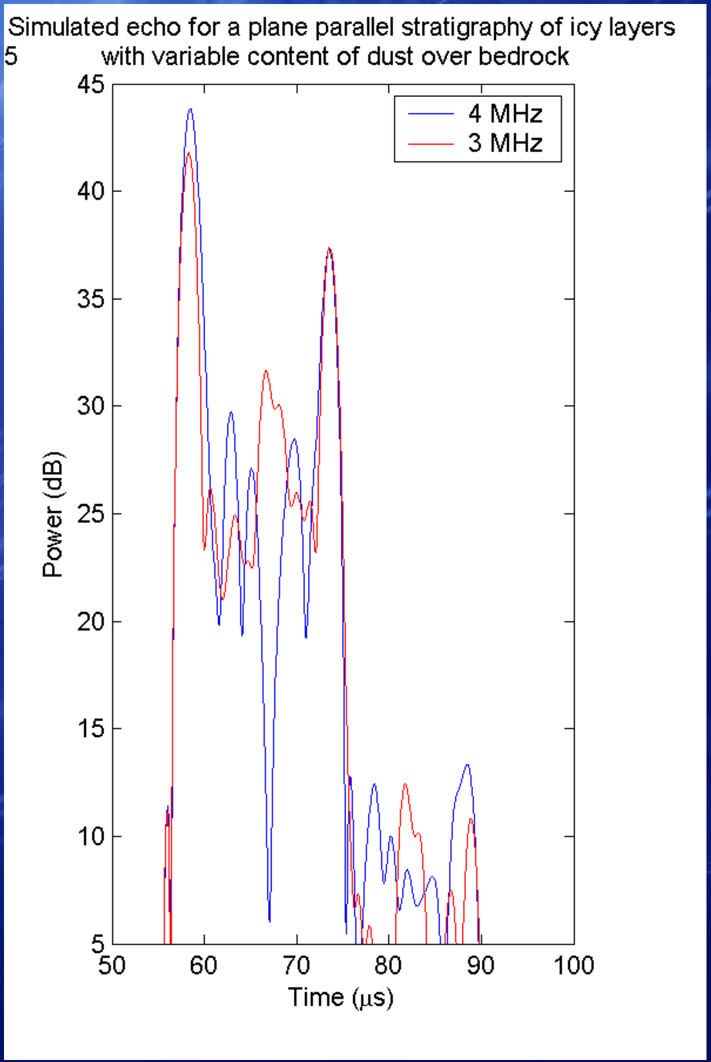
- For Ganymede (and Callisto) the crust is thought to be a mixture of ice and rock:
  - ✓ The exact percentage of rock is not known, it is expected to be low.
  - ✓ The ice crust could contain salt, similar to sea ice on Earth.
  - ✓ The exact amount of salt and how that amount changes with depth is also unknown.

Properties of Sub-Surface

- It is expected that the subsurface of Ganymede will contain a number of dielectric discontinuities associated with geologic structures and processes such as:
  - ✓ Cryolava flows;
  - ✓ Tectonic structures;
  - ✓ Impact-related structures.

- These discontinuities will be modeled both analytically and through numerical models of subsurface propagation.

- The simplest numerical models are one-dimensional propagation models such as those already used in estimating MARSIS and SHARAD performance over the Martian polar layered deposits.

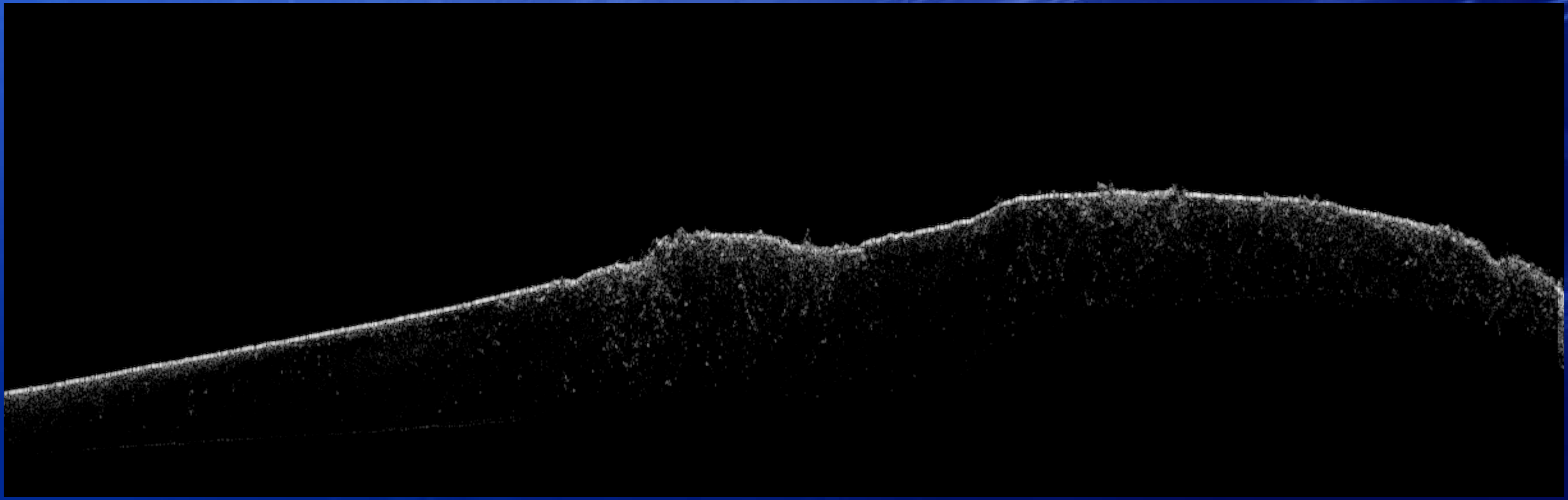


Properties of Clutter

- Surface clutter will be modeled both analitically and through numerical models of surface scattering already developed to interpret MARSIS and SHARAD data.

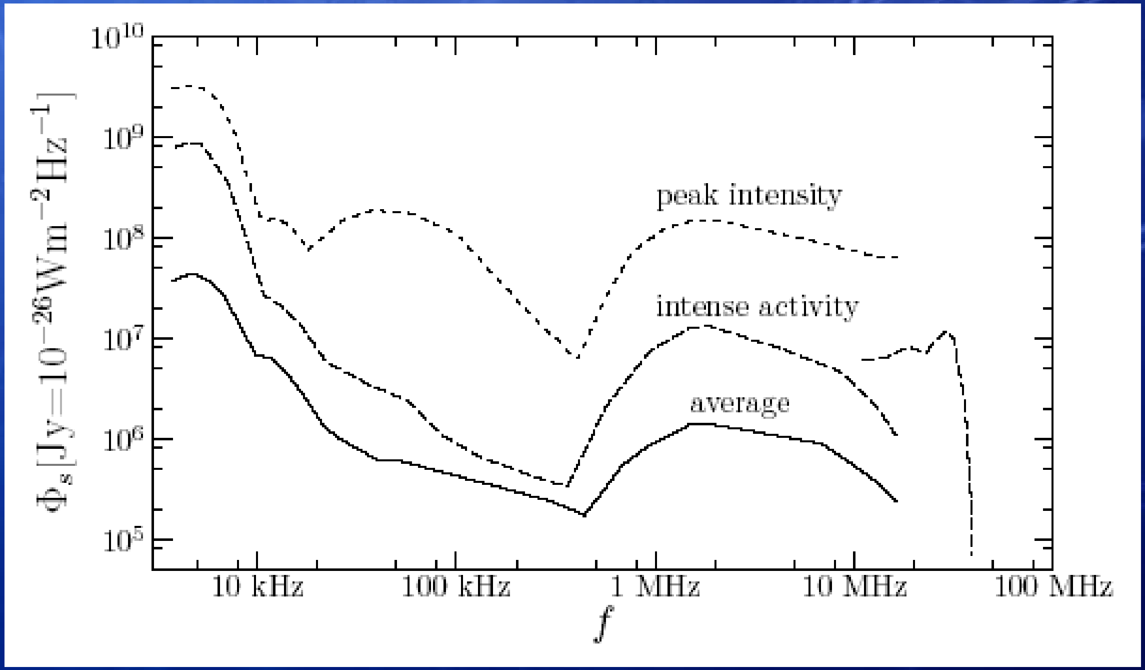
- Digital elevation models of the surface of Ganymede (and Callisto) are required, but they are few and of different quality.

- DEM's of terrestrial and other planetary analog sites, as well as terrestrial measurements from airborne GPR's, can be used as proxies.

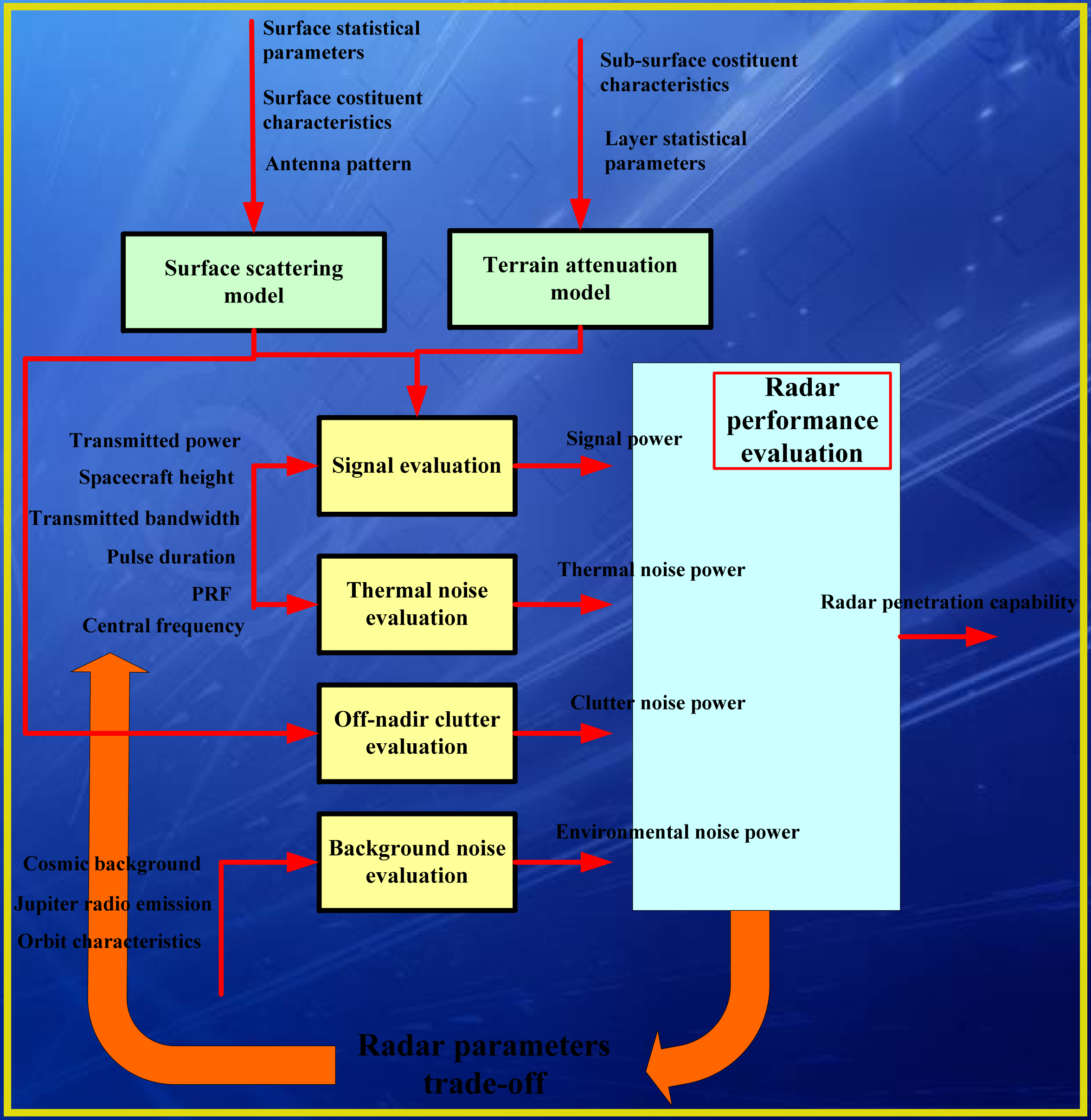


Selection of Central Frequency

- The central frequency should allow the required penetration, after modeling the frequency-dependent factors affecting signal-to-noise ratio:
  - ✓ Jovian radio noise;
  - ✓ Dielectric permittivity of the crust;
  - ✓ Surface and volume clutter.

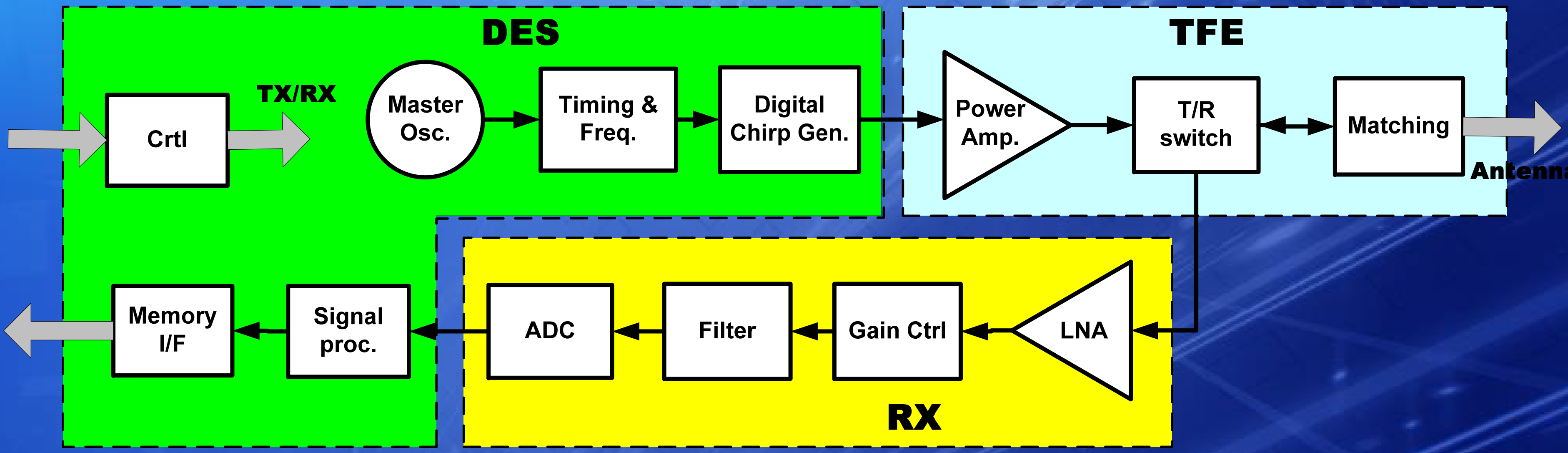


Instrument Performance Model



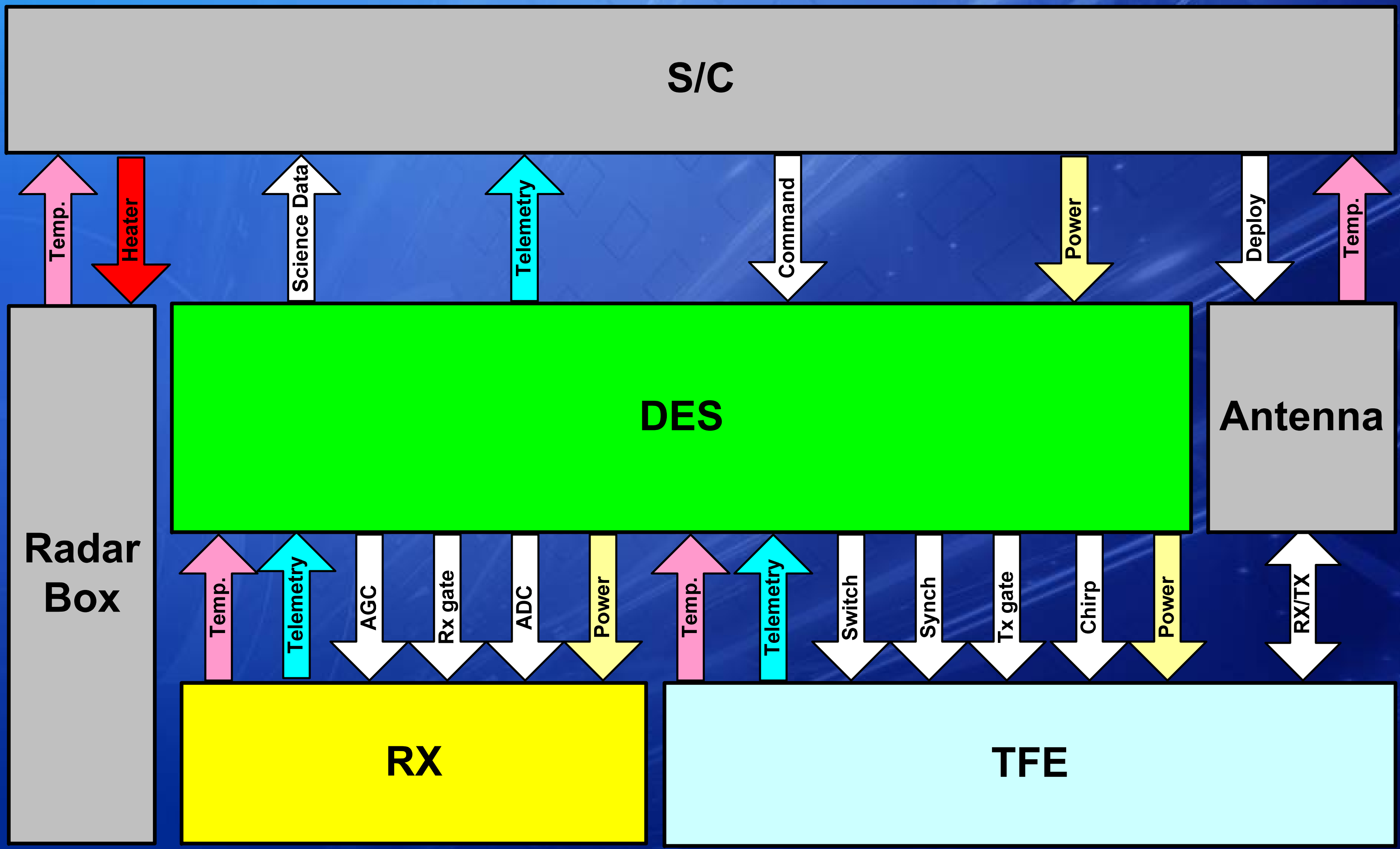
Instrument Performance Output

SSR Block Scheme



- TFE – Transmit Front-End
- DES - Digital Electronic Sub-system
- RX - Receiver

SSR Interfaces



Synergies with Other JGO Payloads

Instrument companion	Component/Property	Radar products	Companion products
MRC, WAC	relief	surface echoes	structures at spatial scales larger than SSR resolution
MRC, HRC	roughness	reflectivity	structures at spatial scales between SSR wavelength and spatial resolution
MRC, WAC	geology, geomorphology	radargrams, DEM	structures and materials at the surface
MLA/LA	roughness	reflectivity	structures at spatial scales between SSR wavelength and spatial resolution
MLA/LA	relief (cross-validation)	DEM	DEM
VIRHIS	Composition and physical state of minerals, ices, organic matter	propagation, reflectivity, dielectric constants	absorption bands, compositional maps
VIRHIS	relief at the ~100m scale	surface echoes, DEM	auxiliary data (acquisition geometry), sampling of the BRDF
UVIS	Composition of ices, molecular solids	reflectivity	absorption bands, compositional maps
TM	crustal/upper mantle structure and dynamics (upwelling, downwelling)	radargrams, sub-surface volume scattering	thermal anomalies, geothermal flux

Development of the Antenna

- Deployable 10 m dipole with new thermo/mechanical design with respect to the SHARAD antenna.
- The main technology developments necessary for SSR are related to the antenna and the study of its mechanical deployment:
  - ✓ ESA ITT O/1-5973/09/NL/CP for *Demonstration of the deployment of a highly integrated low power ice penetrating radar antenna*. The study must achieve TRL=4 for the antenna by end 2011;
  - ✓ TASI proposal selected by ESA (negotiation meeting to be done shortly).
- The main objective of the activity is to design, analyze, manufacture and demonstrate by test the deployment of a Demonstration Model (DM) of the proposed technology.
- A further development phase should be planned in order to achieve TRL≥5 by end 2012.

Data Volume and Compression

- High compression rate is necessary.

- Main parameters to define:
  - ✓ Receiving window duration;
  - ✓ Signal sampling frequency;
  - ✓ Number of bits per sample;
  - ✓ Number of presummed echoes.

- Trade-off between pulse duration value, data rate, SNR and the other parameters of the sounders in order to select the sampling architecture.

Conclusion

- Study priorities
  - ✓ Ganymede surface and sub-surface models;
  - ✓ Selection of the central frequency of SSR;
  - ✓ Definition of on-board data processing;
  - ✓ Refinements of power budgets and data rates;
  - ✓ Study of radiation issues for each sub-system of SSR;
  - ✓ Complete list of TDA;
  - ✓ Sharing of the antenna with *Radio and Plasma Wave Instrument* (RPWI)?

- At the present no critical problems have been identified.

Status of the Study

- ESA issued the first call for “Declaration of Interest in Science Instrumentation” for the EJSM/Laplace in March 2009.
- SSR study started in November 2009 with a set of teleconferences.
- First meeting in Trento (Italy) on 18 December 2009.
- Second meeting expected in March 2010.
- Contract with ASI is in phase of definition.