An Insight into Research and Development activities in Signal Processing for Communications

cnes

. Toulouse

CNES MISSIONS

- Assists government in shaping French space policy
- Represents France at Esa and in international actions
- Develops centres of excellence in technology and space systems
  - to provide technical and mission analysis expertise for the scientific community
  - to bear the burden of risk to help industry develop certain advanced technologies
- Promotes and encourages uptake of space applications
- Provides the capacity to conduct operations for customers
- Accomplishes prestige missions

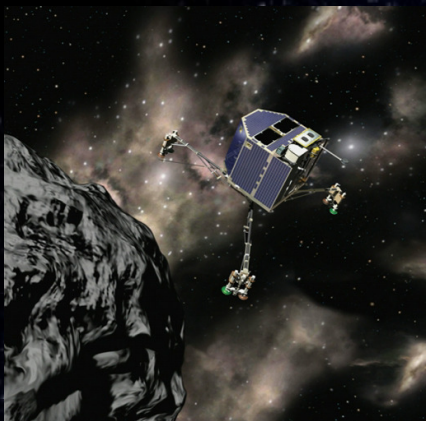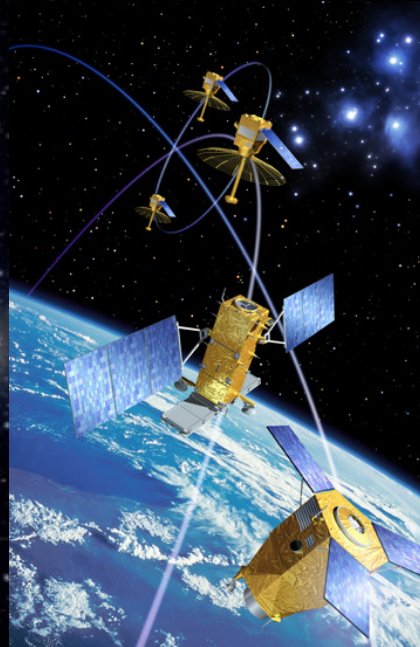# ARIANE
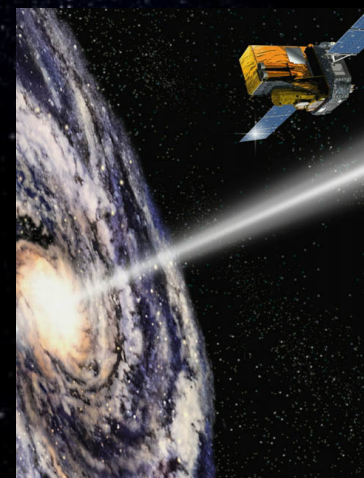# Launchers family

Ariane 5

Soyouz

Vega

The programmes

Rosetta

Jason
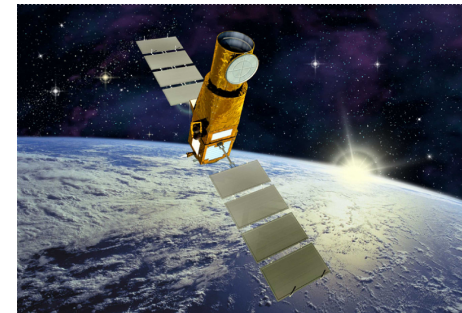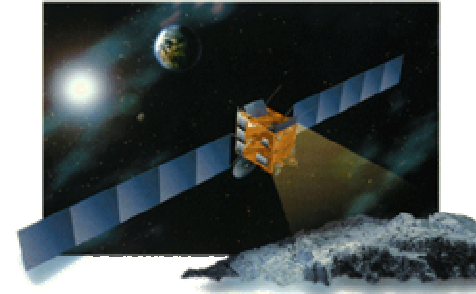
Pleiades

@bus

Integral
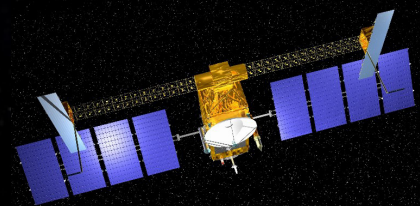
Galileo

ROSETTA mission

- Launched, March 3 2004
- Lander to be dropped on Churyumov-Gerasimenko
- To Study the comet 's nucleus
- Cnes / Esa / Nasa

Corot mission

⇨ Launch scheduled at the end of 2005

⇨ Stellar seismology and search for exoplanets

⇨ Partnership: Austria, Belgium, Esa, Italy, Estec, SSD Germany

Earth observation operational program
over 15 year's uninterrupted service

- SPOT 1 (86), SPOT 2 (90), SPOT 3 (93) : 10-metre resolution
- SPOT 4 (98) :
  New spectral band and Vegetation instrument
- SPOT 5: May 4, 2002
  3-metre resolution
  (+ HRS and VGT2 instruments)
- Military programmes:
  - Helios IA laun
  - Helios IB
  - Helios
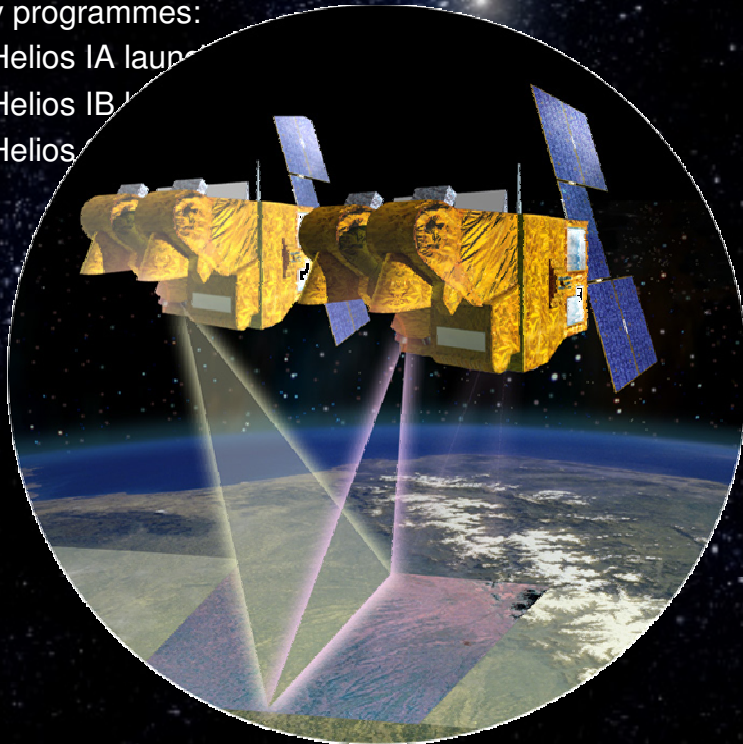
The future : PLEIADES
small satellite constellation

- Dual-use programme :
  - High-resolution optical and radar satellites
    aly.

Satellite Telecommunications
Keeping the space industry competitive

- New plans Telecom TCS21 (2007 - 2010)

  – System testbeds for prime contractors and operators

  – Development of new breaking through technologies => 7t-10t platform

  – Develop emerging technologies

- AGORA programme

  – high-speed Internet access

- Future @sat and @bus preparation programmes with ESA

  – @bus to keep our space industry competitive

  – @sat at european level
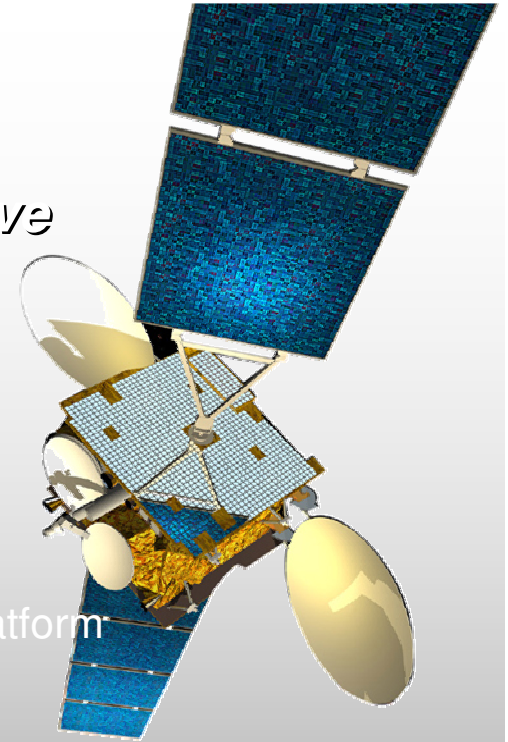
SATELLITE NAVIGATION
Joint initiative of European Commission and Esa

- Phase 1 - EGNOS :
  - The Esa/Cnes/European CAA team is based at the Toulouse space centre
  - The Toulouse space centre will host the Egnos system testbed and technical coordination centre in partnership with DNA/STNA, the French air navigation directorate and technical services
- Phase 2 - GALILEO
  - 21 satellites in medium-Earth orbit
  - 3 geostationary satellites
- Strategic and commercial issues
  - Independent European capability
  - Commercial services and terminals market

The information path from sensor to users

Source

On-board receiver

On-board data processing

Transmission

Our goal is to study and develop high data rate signal processing technologies:
- To improve performances (quality, capacity)
-To reduce the weight, volume and power requirements
of space communication systems

Users

Extraction of information

Reception
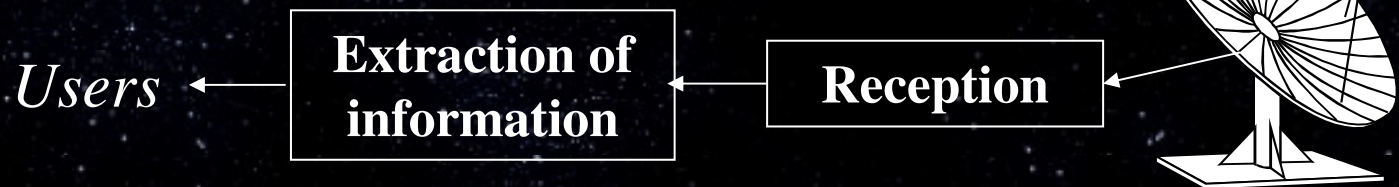
- ## Source Coding :
  - ### Intra-band coding

	Decorrelation	Quantization	Coding	CR
SPOT 1-4	DPCM	Non-Uniform Scalar	Fixed	1.33
SPOT 5	DCT	Uniform Scalar	Variable Length + Regulation	2.82
PLEAIDES	Wavelet	Uniform Scalar	Variable Length + Regulation	5

  - ### Multi-or hyper-spectral coding

Intra-band Codec

Intra-band Codec

Intra-band Codec

Intra-band Codec

Intra-band Compressor :
exploitation of spatial correlation

Multispectral Codec

Multispectral Compressor :
exploitation of spectral & spatial correlation
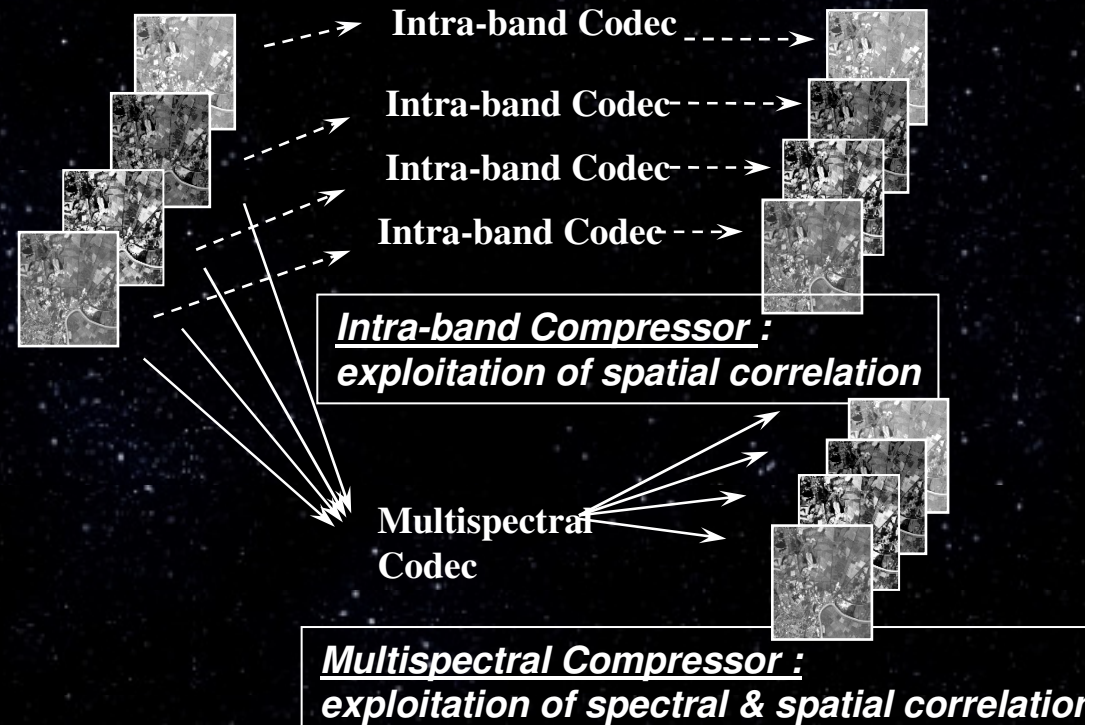
- **Selective Coding :** To enhance the image quality in regions of interest (ROI) such as non-cloudy areas, specific targets, …

Specification(if necessary)

Selection / Detection → Region of Interest → Control Algorithm

Image

Compression Algorithm → Compressed data
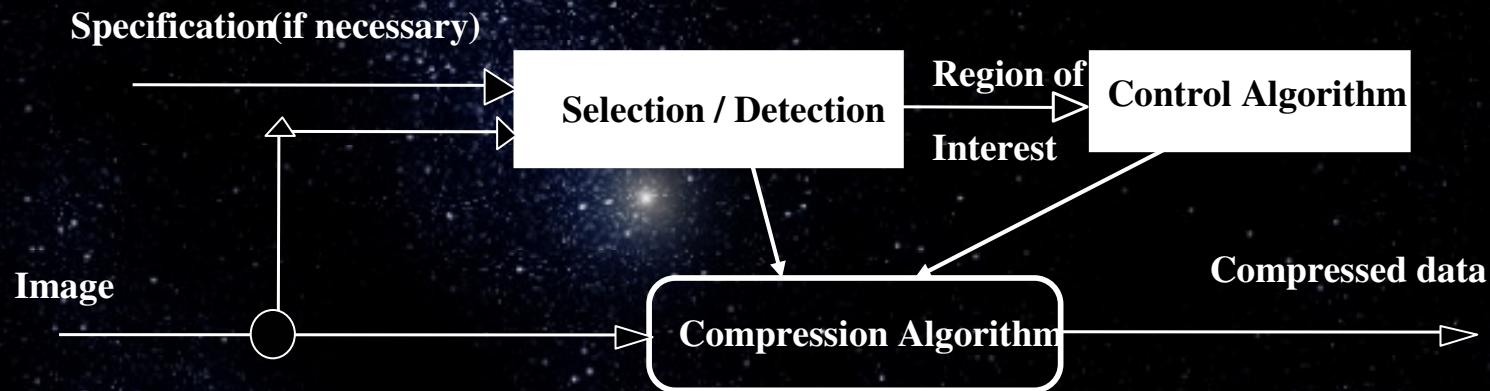
- **Joint Source -Channel Coding**

Shannon's separation theorem

| Source Coding | Channel Coding | Modulation |

Joint Source Channel Coding

| Source and Channel Coding | Modulation |

The information path from sensor to users

Source → **On-board data processing** → **Transmission**

3 type of links with different constraints and optimization criteria

Extraction of information ← **Reception**
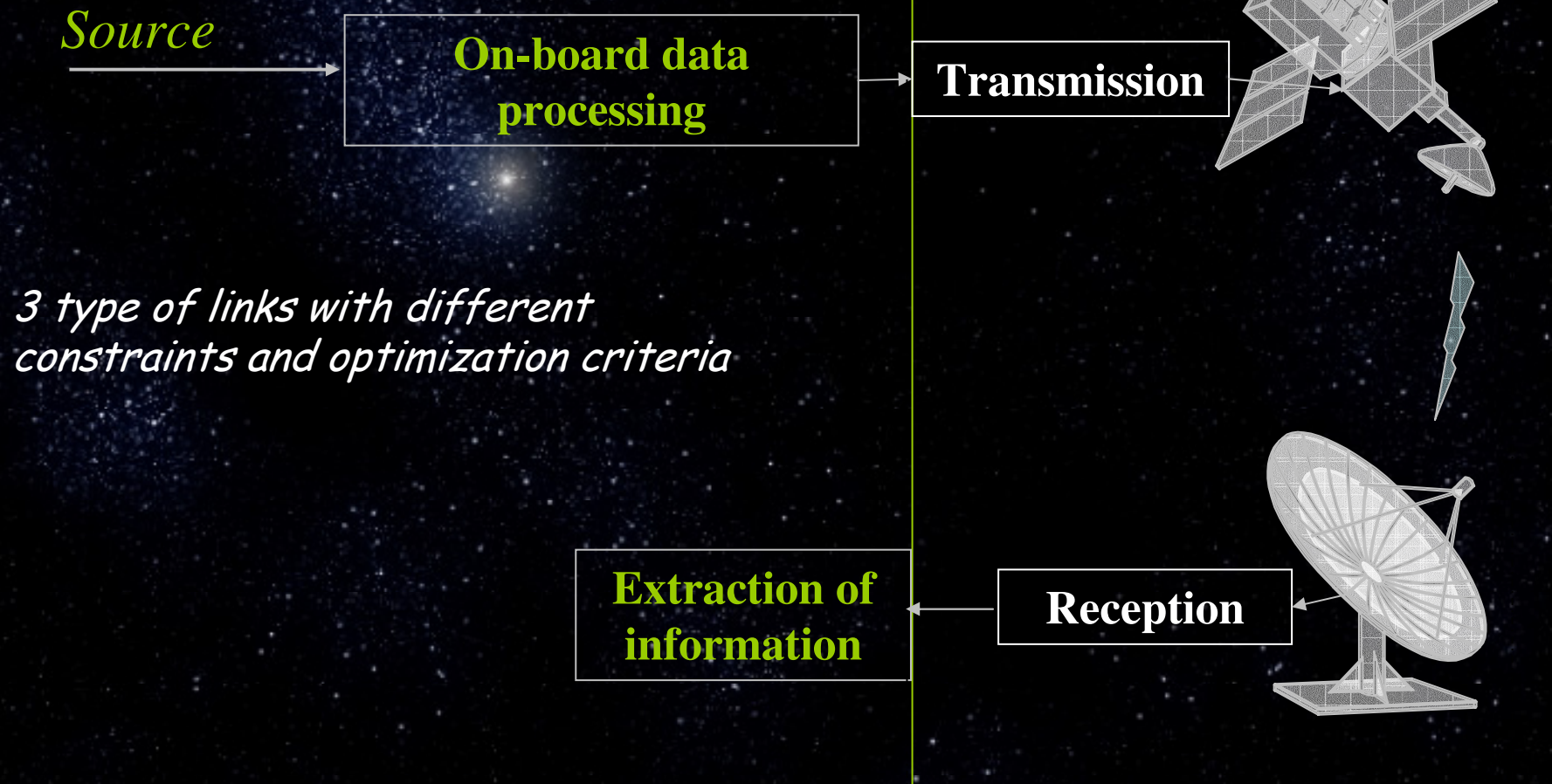
TeleMetry/TeleCommand (TM/TC) links

TM/TC → | Channel coding | → | Shaping Modulation | → | Channel | → **Demodulation** → | Decoding | → | De-framing | →

Turbo-codes Conv.+RS **GMSK Filtered OQPSK** **S-band Doppler Non linear ampli. AWGN** **Iterative demod & decoding** **FER < 10^{-5}**
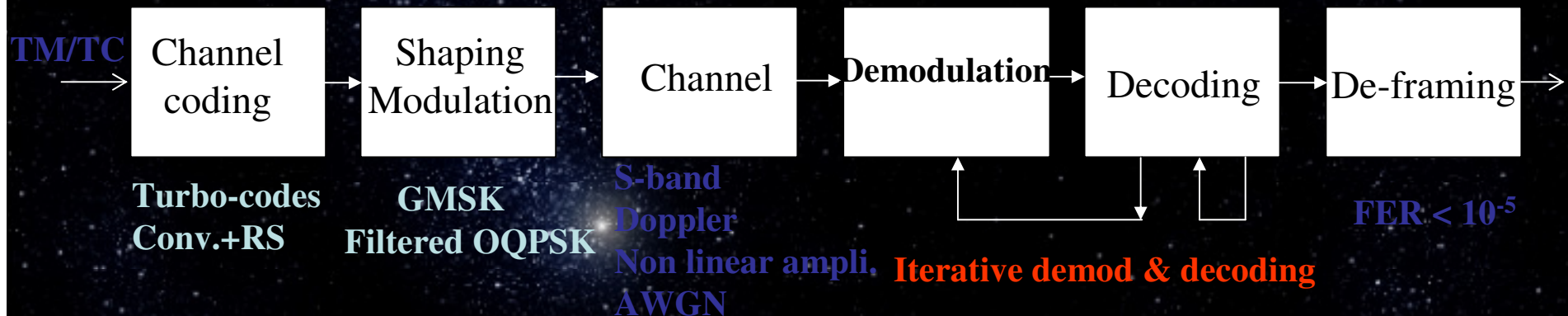
- **Modulation & channel coding are standardized by CCSDS** *(cross-support between space agencies for TM/TC operations)*

- **New CCSDS standards for modulation provide**
  - Better spectrum efficiency (waveform shaping)
  - Better power efficiency (quasi-constant enveloppe)

- **Our research axis**
  - Efficient turbo demodulation and decoding under high Doppler constraints
  - Modulation & demodulation of GMSK and filtered OQPSK

Payload TeleMetry and Telecom forward links

Source Coded Data →

| Channel coding | → | Shaping Modulation | → | Channel | → | **Demodulation** | → | Decoding | → | De-framing | → |

MTCM/RS
LDPCC (DVB-S2)

8PSK SRC
16APSK SRC
Mary CPM

X or Ku/Ka-band
Doppler
Non linear ampli.
AWGN

Iterative demod & decoding

FER < 10^{-10}
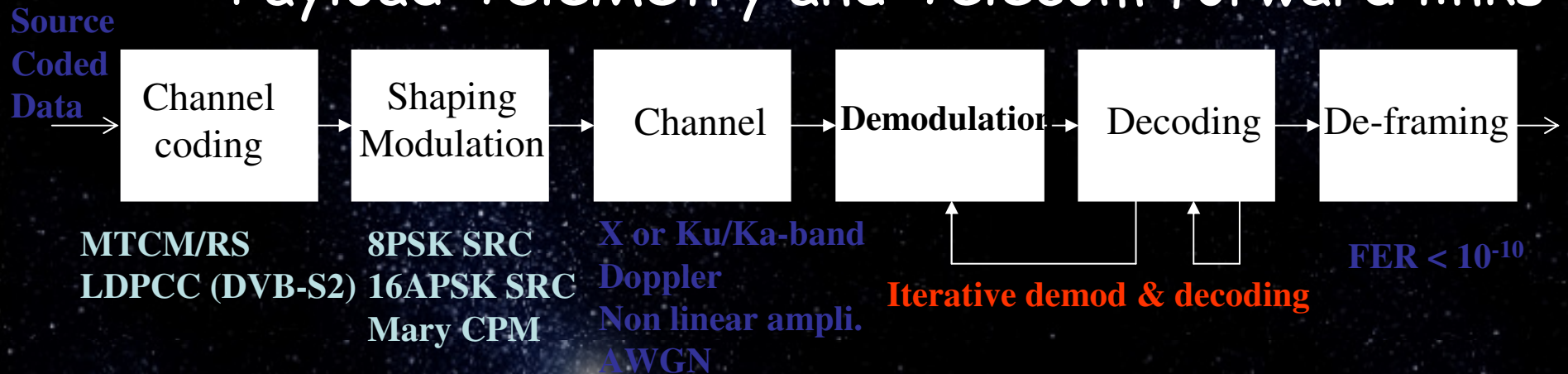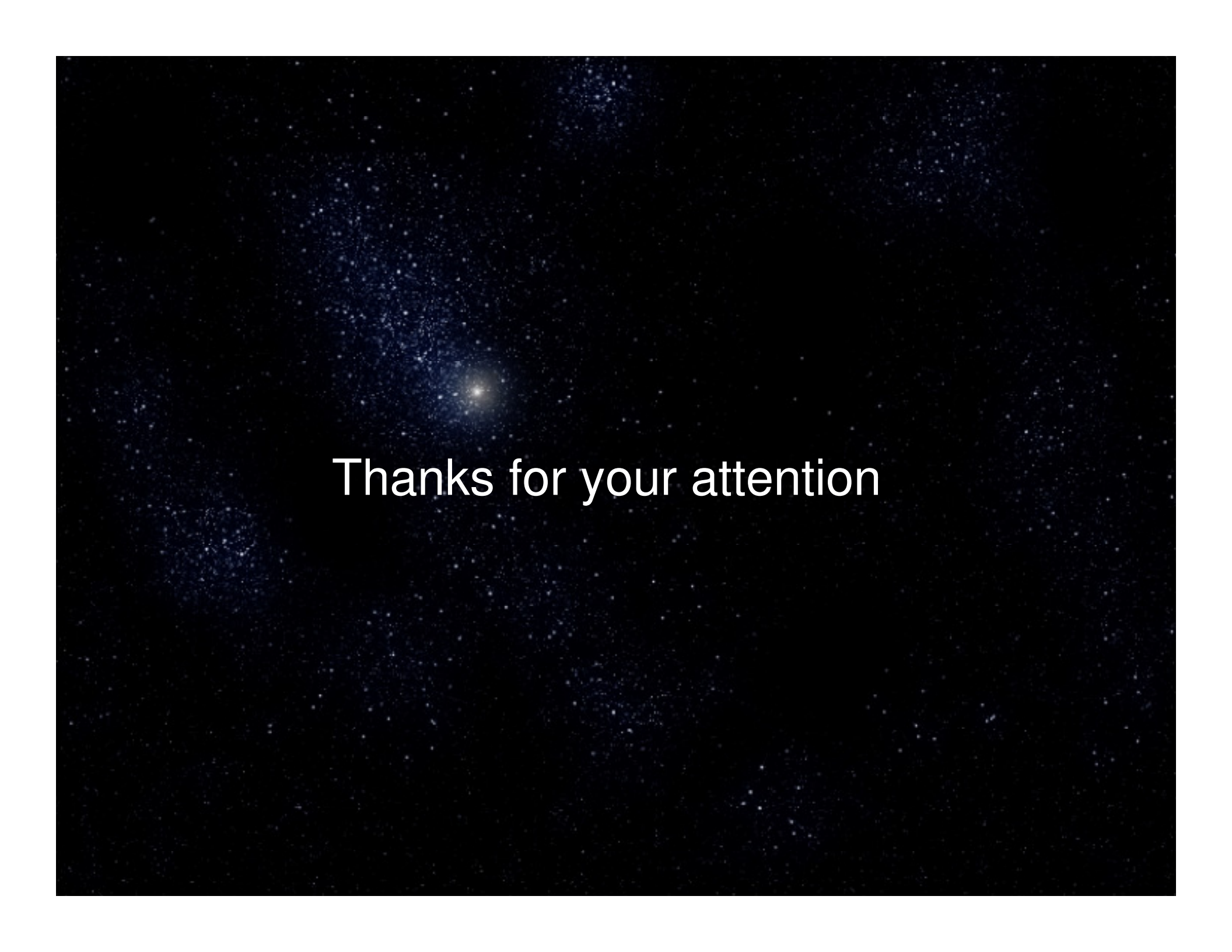
- **Very high data rates** : 10 Mbps up to 500 Mbps
- **Very high spectral efficiency required**
  - CNES development : RS / MTCM 8PSK
  - DVB-S2 : BCH/LDPCC with BICM scheme on 8PSK and 16/32APSK
- **Our research axis**
  - Spectrally efficient waveform shaping for MTCM 8PSK with constraint of constant enveloppe
  - Robust M-PSK continuous demodulation ($M \geq 4$) with low SNR
  - SIHO Reed Solomon decoder to improve concatenated decoding schemes (MTCM/RS)
  - Iterative demodulation and decoding with CPM/turbocodes or LDPCC (EG or IRA)

Telecom satellite return links

User$_i$ Data → Concatenated Channel coding Shaping, Modulation

Adaptive Coding rate and Modulation

Channel$_i$
Ku or Ka bands, GEO satellites : White and Gaussian Rain fading

User$_j$ Data → Concatenated Channel coding Shaping, Modulation

Channel$_j$

S band, GEO (or LEO) satellites : Doppler, Rice/Rayleigh hybridation with Terrestrial networks

Single or Multi Elements On Board Antenna

SI or MIMO Processing DeModulation Decoding Routing

« Turbo » iterative processing and decoding

Remodulation

Remodulation

Multi Elements On Board Antenna

Increasing number of beams on ground

Received Data

$\Rightarrow$ **Improve capacity in term of number of users (satellite links from 64 kb/s to**

- **Active antenna with DBF (Digital Beam Forming) and flexibility**
- **minimize** the **Interference degradation** and **Channel effects (propagation)** by using **fully adaptive coding rate** and **modulation**
- **satellite specific SIMO** or **MIMO « turbo » processing** on **small bursts** (evolution of **Digital BeamForming** to reduce antenna beams size)
- **efficient Anti-Jamming Processing** (frequency spectrum overcrowded)
- comparison between **WCDMA** and **COFDM** and even **UWB, Chaotic Modulatio**
- **Space-Time Codes** for satellites (2*2 and more ?)

Thanks for your attention