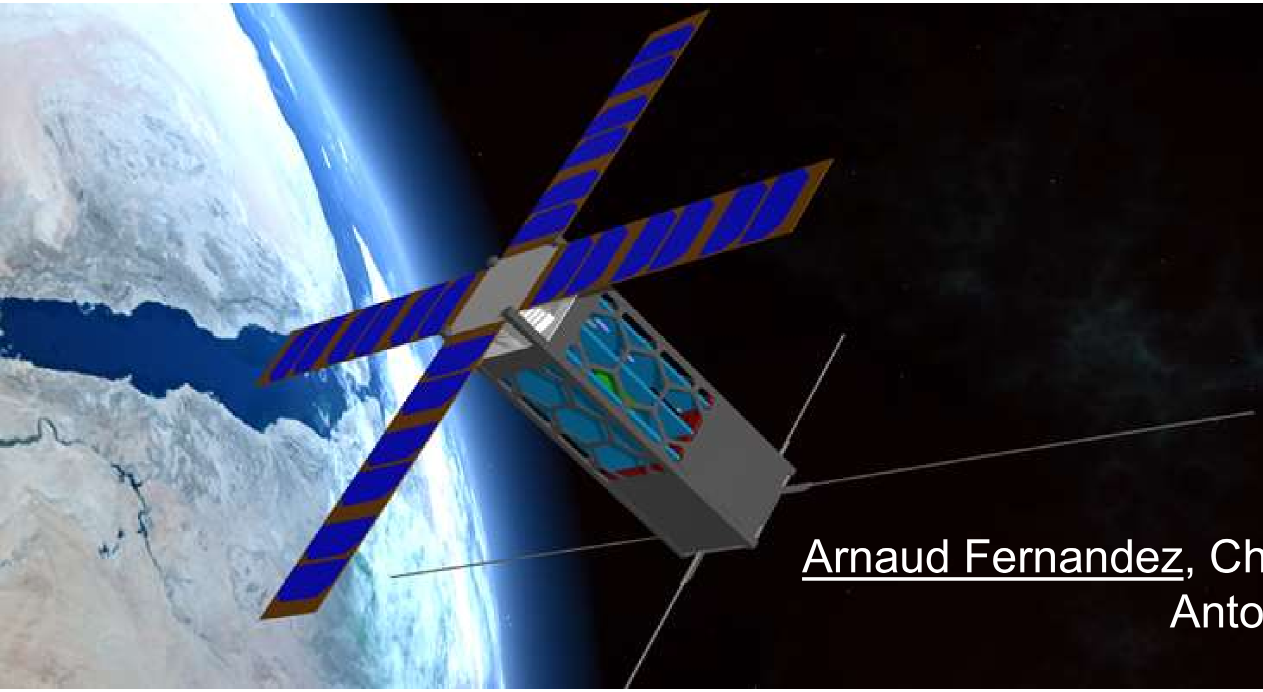
NIMPH

Nanosatellite to Investigate Microwave Photonics Hardware



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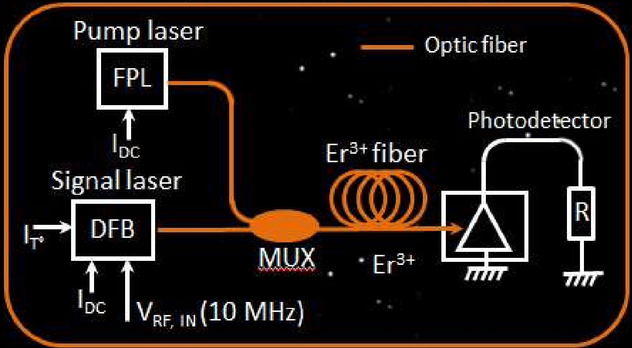
Arnaud Fernandez, Christophe Viallon, Nicolas Nolhier, Olivier Llopis, Antony Coustou, Denis Lagrange

NIMPH mission

EDMon (NIMPH payload)



❑ Telemetry :
UHF 435-438 MHz; 50 to 70 lin/day 180 to 250 kB/day

❑ Scientific interest:
Collecting data on the payload operating and the erbium doped fiber aging through gain and noise figure measurement of optical transmission

❑ Aging factors:
- Cosmic radiation effects:
  - Cosmic radiation effect
  - Van Allen Belt
  - South Atlantic Anomaly
- Weightlessness effect
- Take-off stress

NIMPH 3U nanosat

❑ LEO orbital to be defined
Perigee : 300-600 km
Apogee : 600-1450 km
Period : 90-100 min

Technological constraints
Mass: 2 kg
Electrical consumption : 10 W (15 min daily measurement)
Volume : 300 cm^3

Major challenge inherent to the nanosatellite design
- **Reliability in space conditions.**
- **Anticipate any type of hardware and software failures**

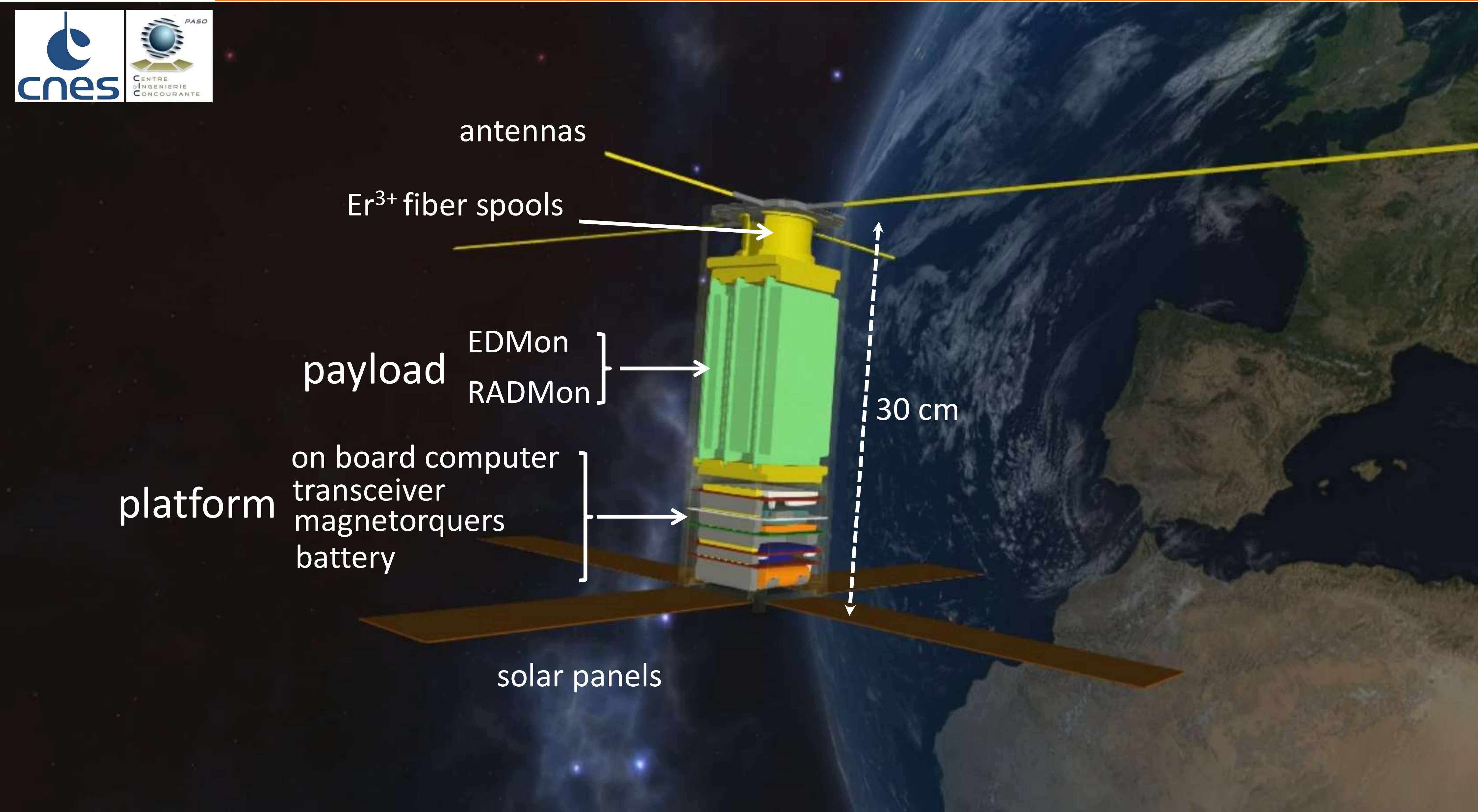
« Design a simple device with minimum technological overbid to avoid failure »

RadMon (secondary payload)
Radfet : Total ionizing dose
PIN diode : Displacement dose
SRAM : high energy particules fluence

Mechanical structure design

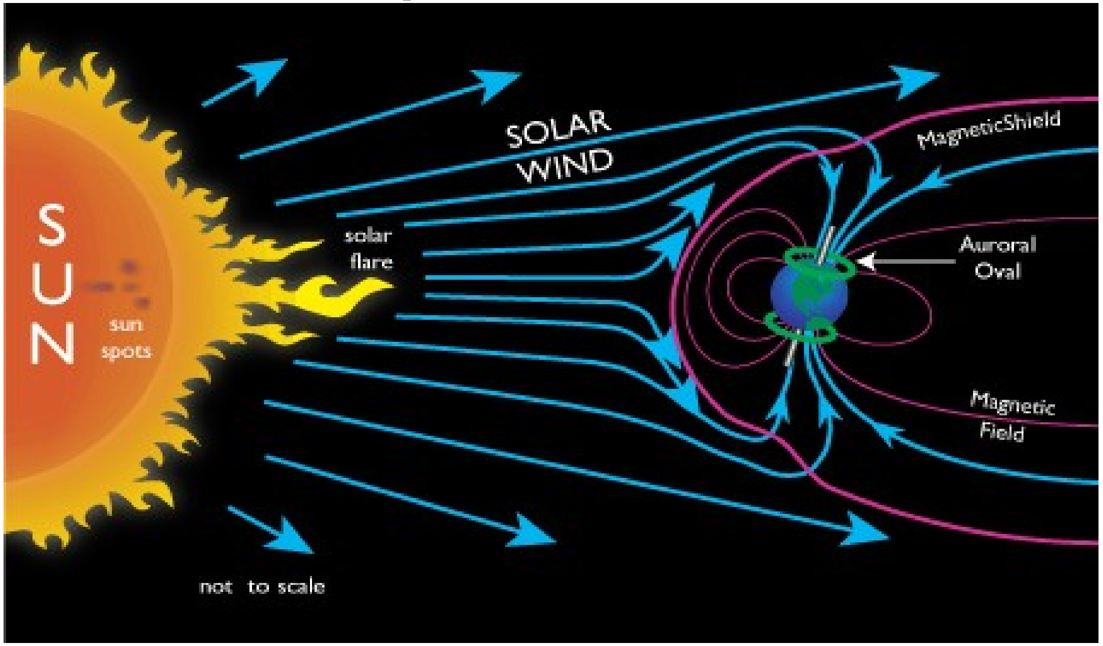
Platform
Spacecraft operations management
Ground segment

NIMPH

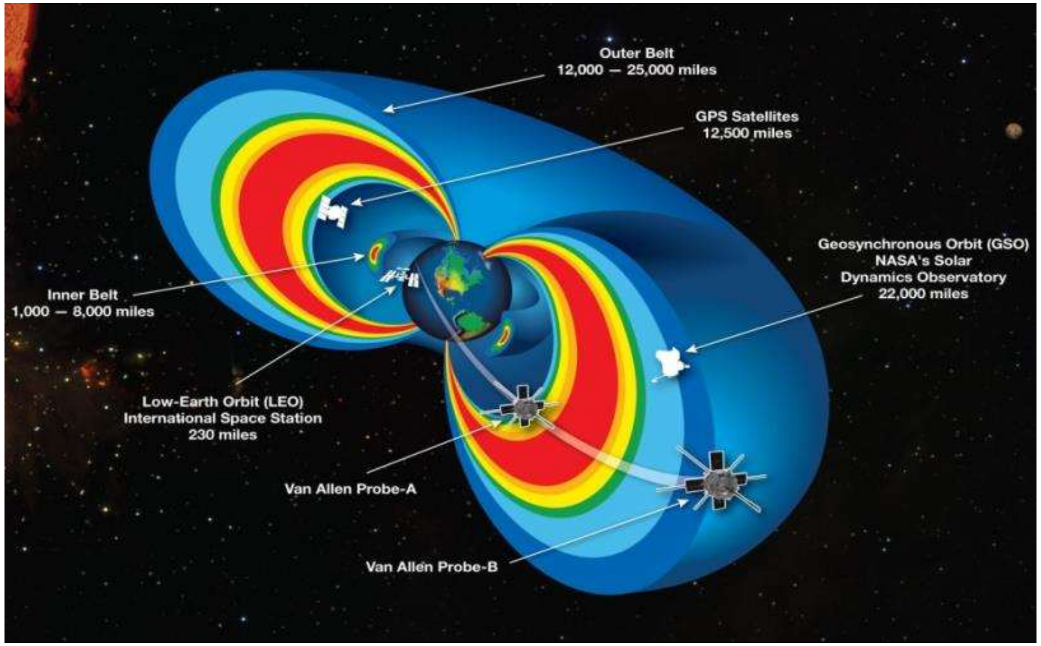

antennas
Er3+ fiber spools
payload
EDMon
RADMon
30 cm
platform
on board computer
transceiver
magnetorquers
battery
solar panels

Space environment

> Radiative space environment



> Earth radiation belts



- > Solar particles
  - Continuous particles emission from the Sun (solar wind)
  - Solar flares and CME: sporadic events
- > Cosmic rays
  - Mainly protons and helium
  - High-energy heavy ions (SEU)

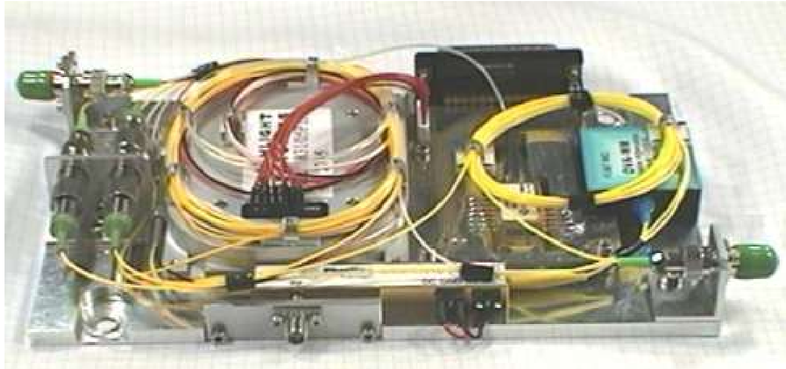
- Modified Sacred orbit : 650 km, 98° inclination
- Orbit period : 90 min
- T° fluctuations: -50, +110 °C
- Cumulated radiative dose : 20 krad on 2 years mission

Context

> **Optomicrowave fibered technologies for future generation of telecommunication satellites**

> **Strong interest due to better performances**
- Bandwidth, mass, EMI, size

> **New payload concepts**
- Generation and distribution of optical local oscillators
- RF frequencies optical conversion
- Optical switching and routing of RF signals (RoF)
- Integrated optical reception head for antennas



ThalesAlenia Space — A Thales / Finmeccanica Company

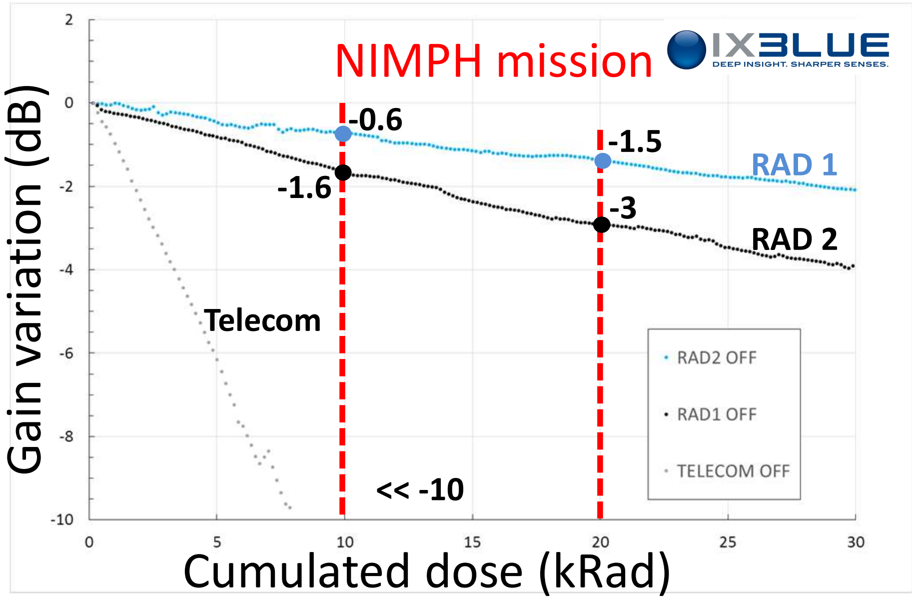
> **Erbium doped fiber amplifier (EDFA) is taking benefit from its reputation for terrestrial telecommunication applications :** Wide bandwidth, high gain, WDM applications, beyond 1 Tb/s

- Numerous experimental and theoretical studies : quantification of RIA (Radiation induced attenuation) impact
- New MCVD preform : drawing of radiation resistant Er^{3+} doped fibers

> **However the developpement of these techno. is slowed down due to lack of mesurements in real space conditions**
- Necessity to prove the maturity of this technology : performance in spatial environment to accelerate the introduction of RoF technologies for spatial needs.

Radiation Induced Attenuation

> Gain



> Experimental conditions

- Co-propagative pumping,
- Pin=-20dBm, P_{pump}=100 mW @ 976nm, $G_{0,init}$~30dB
- Flow:330 Rad/h
- Constant T°

> Origins of the degradation

- rare earth impurities
- co-doping atoms like Al induce structural defects in host matrix
  - Increase of background losses

> Noise Figure

@10kRad	Telecom fiber	RAD fiber
Delta NF	>1dB	<0.2dB

> Real space conditions?

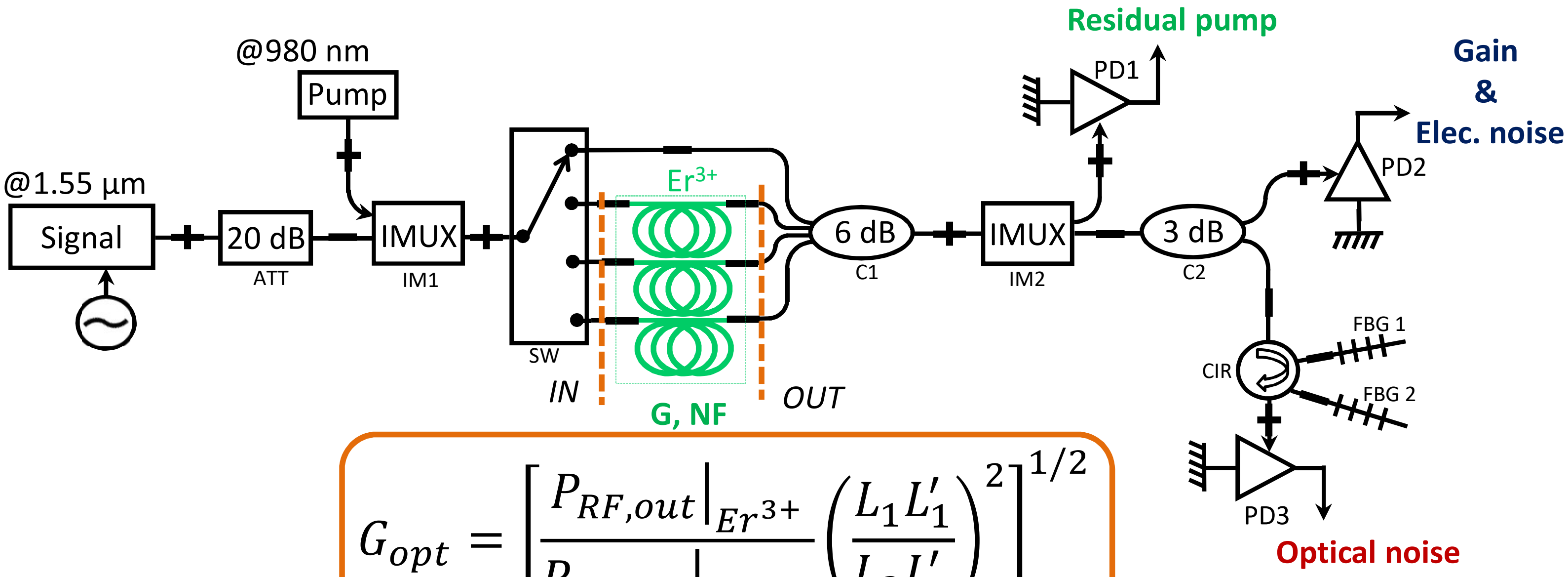
- Flow: 0.6 Rad/h
- Proportionnal degradation reduction?
- Curing effect with pump laser and temperature?

Note : 1 Gy=100 Rad=1J/kg

Erbium Doped fiber Monitoring

Components acronym list :

- Signal : DFB laser
- Pump : Pump laser
- ATT : optical attenator
- IM : isolator multiplexor
- SW : opto-mecanichal switch
- C : couplor
- PD : photodetector
- CIR : circulator
- FBG : Fibered Bragg Grating



$$G_{opt} = \left[\frac{P_{RF,out}\big|_{Er^{3+}}}{P_{RF,out}\big|_{shunt}} \left(\frac{L_1 L'_1}{L_2 L'_2} \right)^2 \right]^{1/2}$$

Gain measurement

- 10 MHz direct DFB laser modulation
- Detection of the amplified intensity modulated laser carrier
  - Photodetection and 10 MHz filtering of AC component.
- Passive components degradation before and after Er^{3+} fiber canceled with switching technique (SW1) :
  - Shunt used for calibration in the IN and OUT planes

> Reduced number of components
> No technological overbid
> Allows 3 erbium doped fiber under test
> However high reliability for any single component is mandatory

Quantum-beat-noise-limited NF

> Two embedded techniques

> IEC definition :

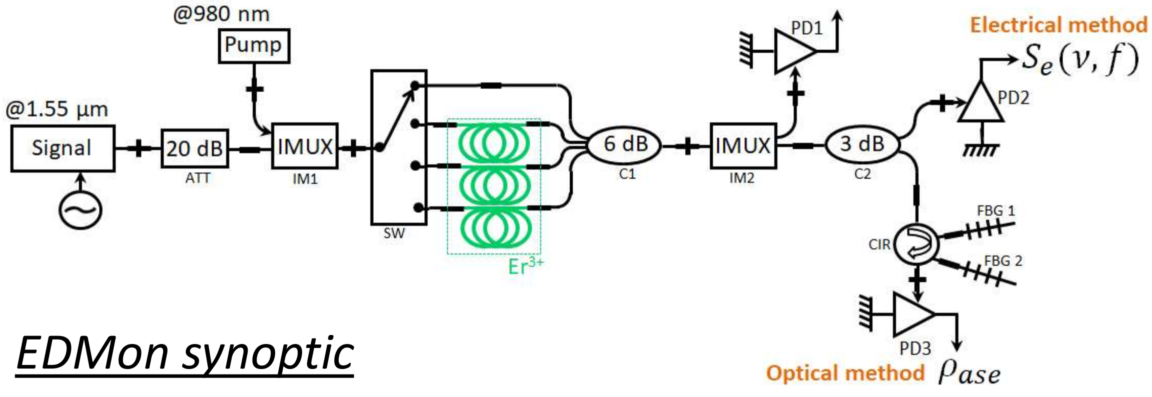
> > Optical method

$$F = \frac{2\rho_{ase}}{h\nu G}$$

> > Electrical method

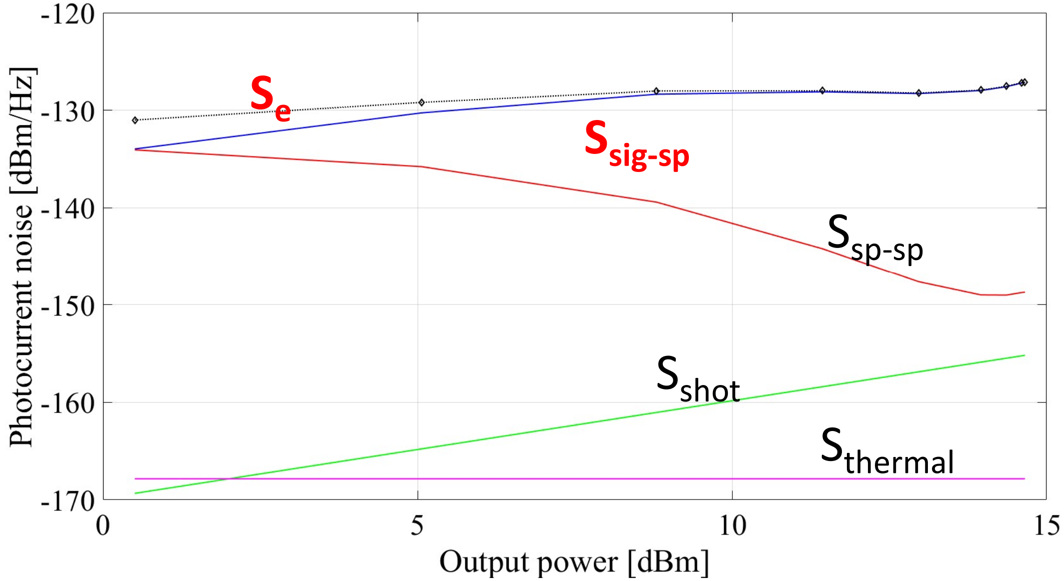
$$F = \frac{S_e(\nu, f)}{2h\nu G^2 P_{in}}$$

- Ability to correlate NF measurement results between different laboratories improved when this definition is used
  - Shot noise limited laser source
  - Identification of the laser spontaneous emission beat noise



EDMon synoptic

$S_e = \sum S \neq S_{sig-s}$ **mismatch with IEC definition**



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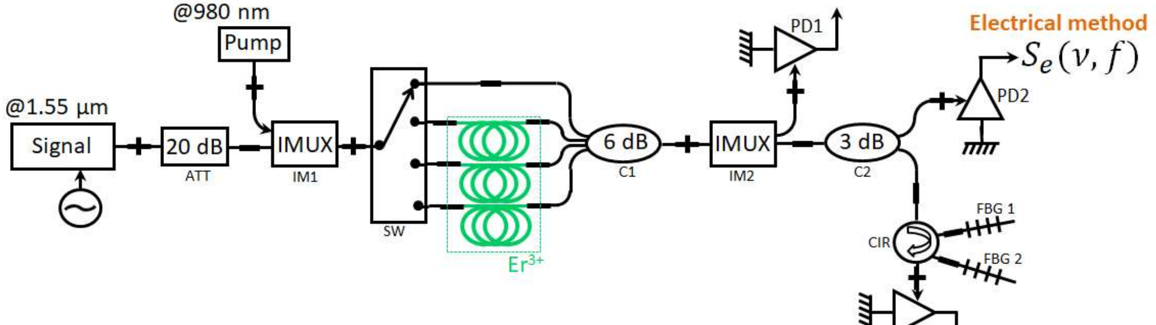
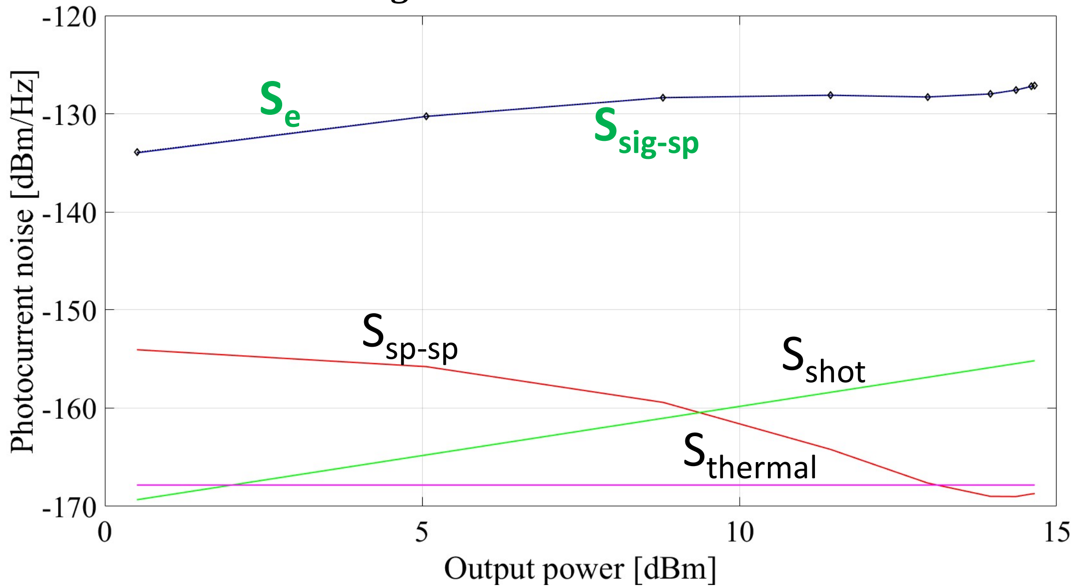


EDMon synoptic

$S_e = \sum S = S_{sig}$ **match with IEC definition**



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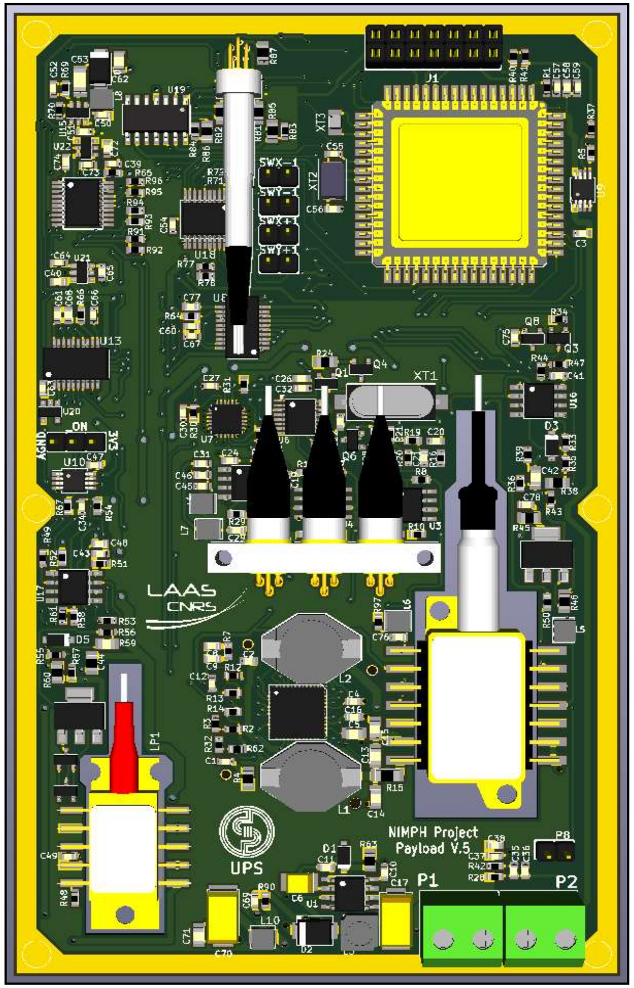
EDMon : integration

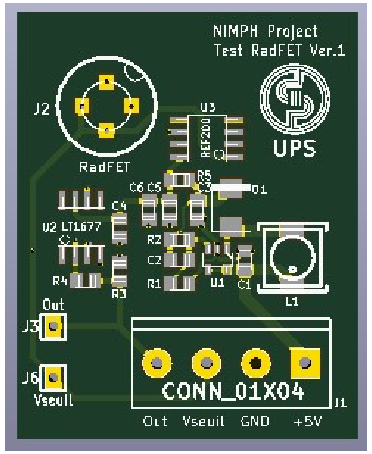
> Optoelectronic board



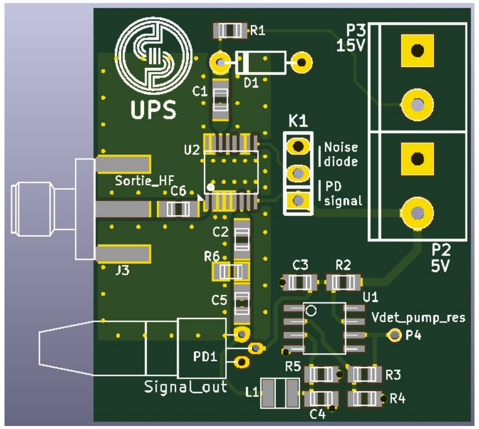
Intern. M2 ESET 2018, F. Titeux

> Optimizations
- Compatibility with metrology
- Reliability tests
- Integration
- Consumption

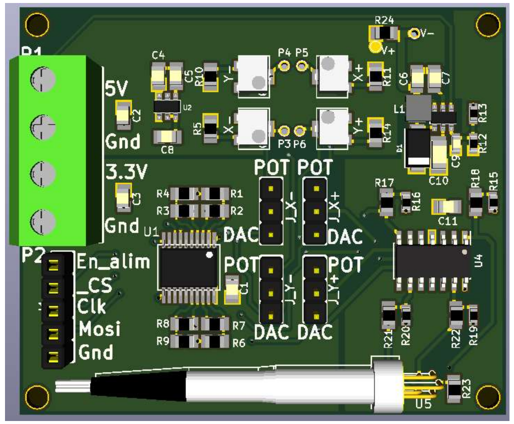
RadFET test card



Noise test card



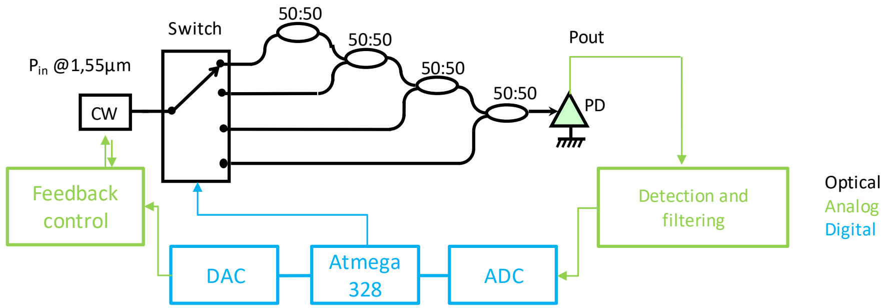
Opto switch test card



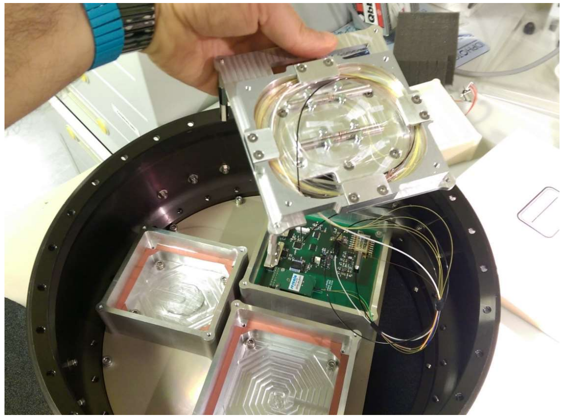
Reliability campaign

> Measuring Optoelectronic in a Rocket Experiment (MORE)
- Collaboration between Supaero and EEA ESET Master students

Sercalo's coaxial type 1x4 switch

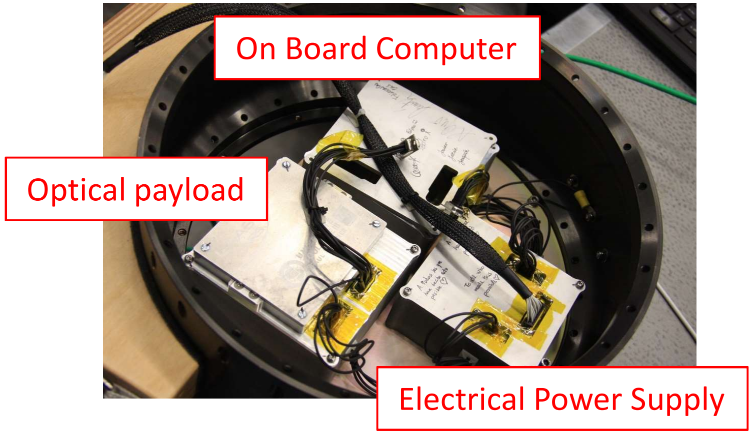


Optical payload synoptic

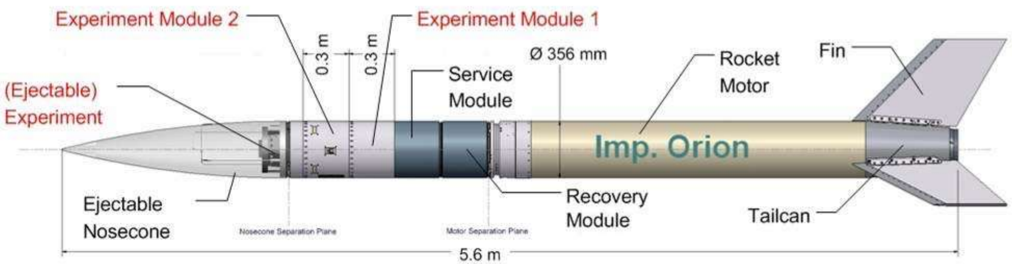


Optical payload integration (dec. 2017)

> Goal :
- Test the structural integrity of optoelectronic devices used in EDMon
  - MORE optical payload designed by University Paul Sabatier students
- Test the proper functionality and reliability of the OBC
  - OBC designed by ISAE-Supaero students in both hardware and software



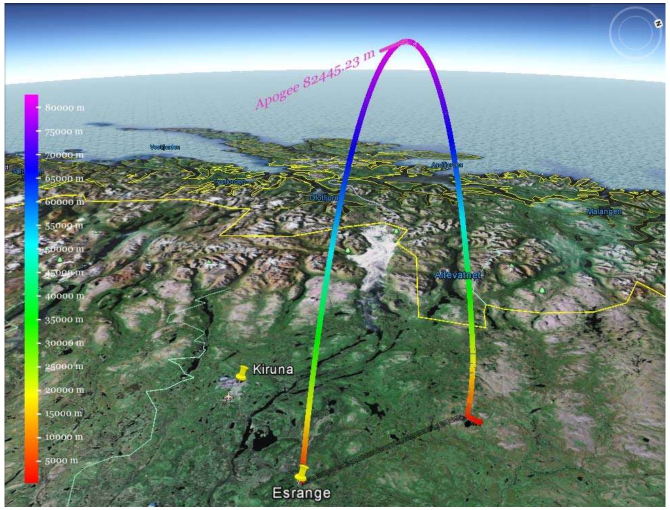
MORE payload



> 18g max. acceleration
> 80 km apogee
> 500 kg

Reliability campaign

> Rexus 24 launch march 12th in Kiruna (Sweden)



> Typical flight timeline

EVENT	Time (s)	Altitude (km)	Range (km)
Lift-off	0.00	0.332	0.00
Burn-Out	26.00	20.38	2.83
Nose Cone Ejection	61.00	52.73	8.89
Motor Separation	66.00	56.39	9.76
Apogee	140.00	82.45	22.42
Parachute Opening	~380	4.60	~40
Payload Impact	~800	0.6	42.77

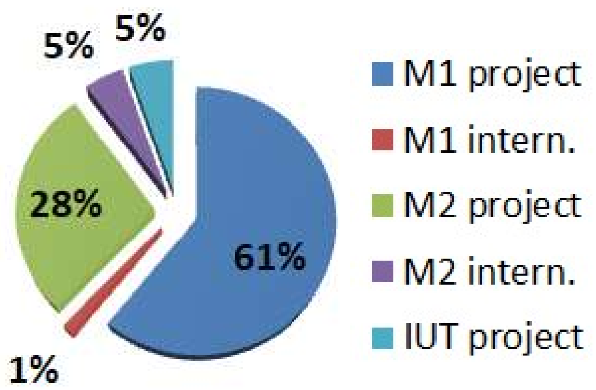
> Real flight

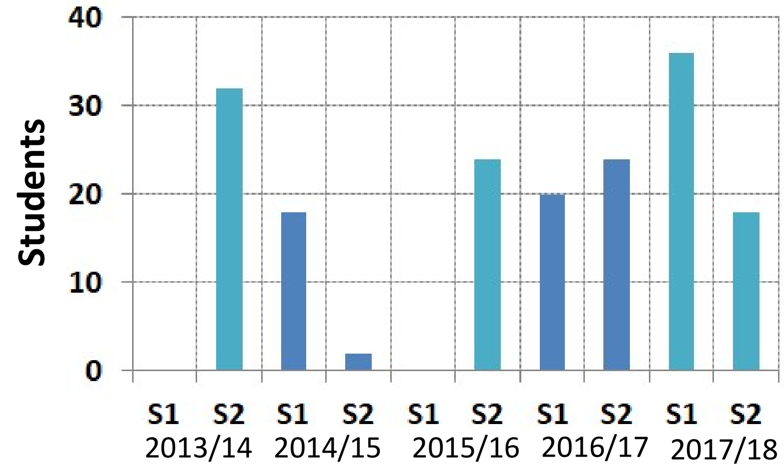
- Not nominal
- 5 km altitude due to rocket failure
- Payload was preseved
- Second chance with Rexus 25

Manpower and perspective

> EDMon manpower

- Students





- Supervisors:
  - Olivier Llopis (DR,MOST)
  - Nicolas Nolhier (Pr,ESE)
  - Christophe Viallon (MCF-HDR,MOST)
  - Arnaud Fernandez (MCF,MOST)

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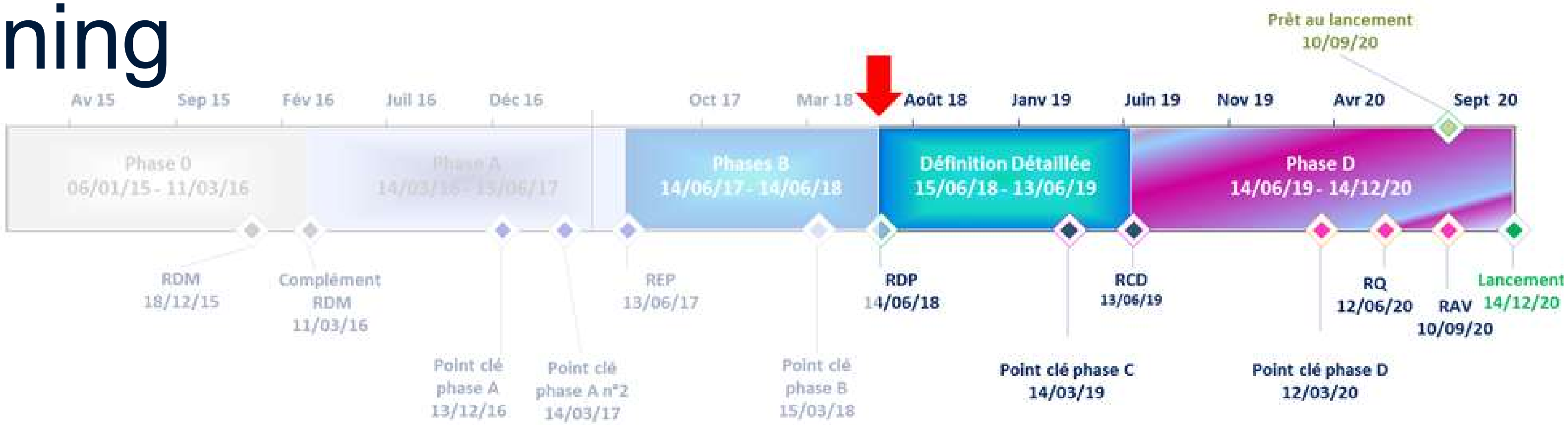
> NIMPH planning



Questions?

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