TERRA FORMA – 2021-2028
« Investment for Future » program

Designing and testing a standard observation platform of socio-ecosystems in the Anthropocene

Eclipse IoT Day, January 19th 2023 @Grenoble

Laurent Royer, Laboratoire de Physique de Clermont-CNRS,
University of Clermont Auvergne

The TERRA FORMA Collaboration

Innovative sensor networks to understand the Planet Habitability

Anthropocene: proposed geological **epoch dating** from the commencement of significant **human impact** on Earth's geology and ecosystems

→

Terra Forma project will help to understand the **Planet Habitability**

↓

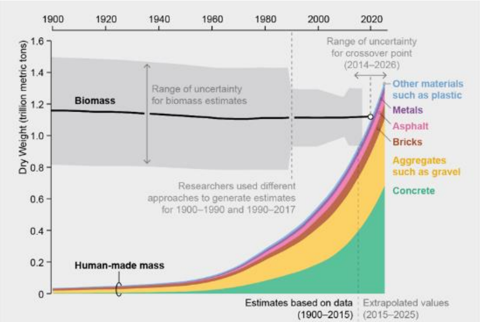
4 key challenges for Planet Hab.

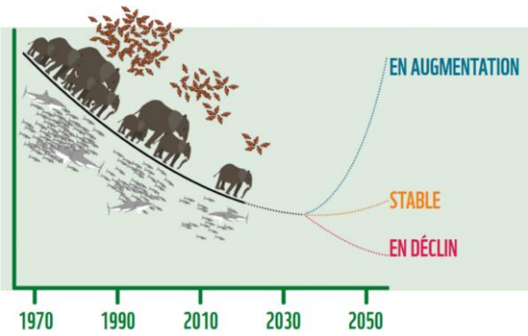
Water ressources

Chemical pressure

Soil capital

Biodiversity habitats





Biodiversity collapse of 68% since 1970. WWF 2020

↓ To understand

Innovative sensor networks deployed at environmental **observation sites**

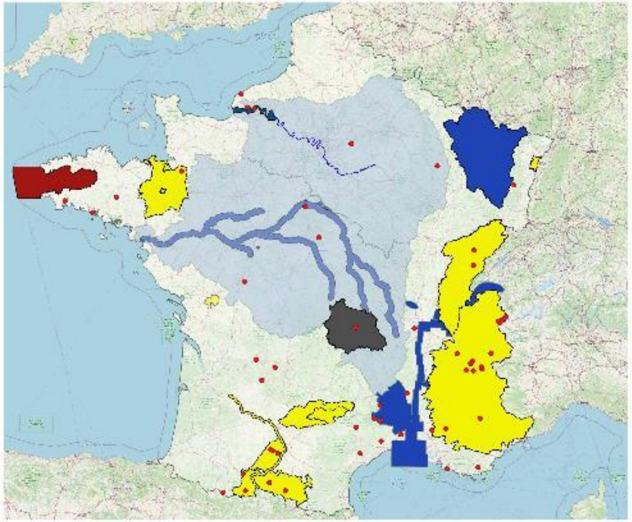
←

Development of:

- Smart sensors
- **Communication infrastructures**
- Social infrastructure[1]

[1] TF must be connected to the society to produce the needed social change for better social ecosystems more resilient and sustainable

Interdisciplinary instrumented observation sites



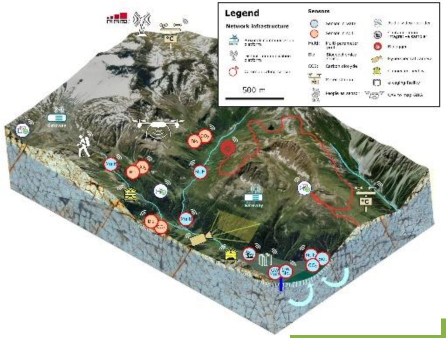
- Currently on the French metropolitan territory :
  - OZCAR: 21 observatories → > 60 instrumented sites
  - RZA: 14+1 “work areas” → > 80 instrumented sites

→ New instruments required to better study the complex biotic-abiotic interactions at a relevant scale

- Program of Terra Forma:
  - Step 1: Co-deployment on 3 pilot sites
  - Step 2: implementation on 12 additional sites
  - Step 3: dissemination of the developed tools

OZCAR: Observatory of the Critical Zone

RZA: “Work areas” network



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Some keys figures of Terra Forma project

Terra Forma project is:

- Collaboration of **42 Laboratories**

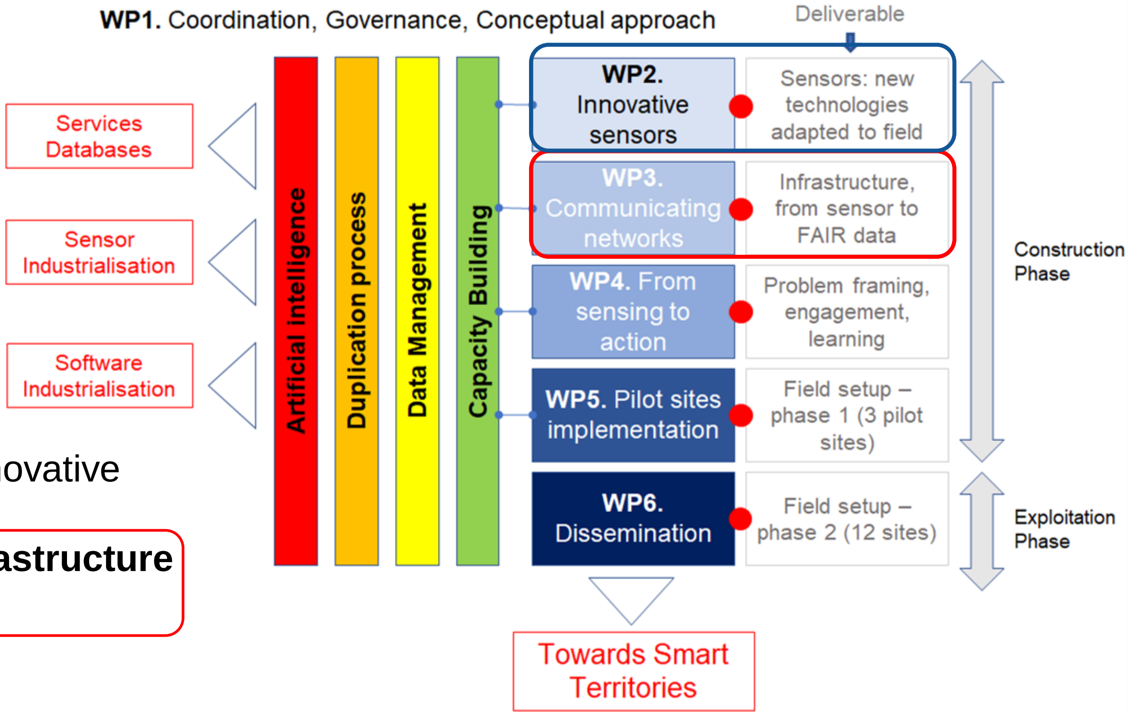
from11 Universities, 11 Institutes of Research

- Budget of **9.6M€**
- From 2022 to 2029
- 6 work packages

➔ **WP2** dedicated to the development of innovative **sensors** adapted to field

➔ **WP3** dedicated to the building of the **infrastructure** to collect, transmit and manage the data

Organization of the project



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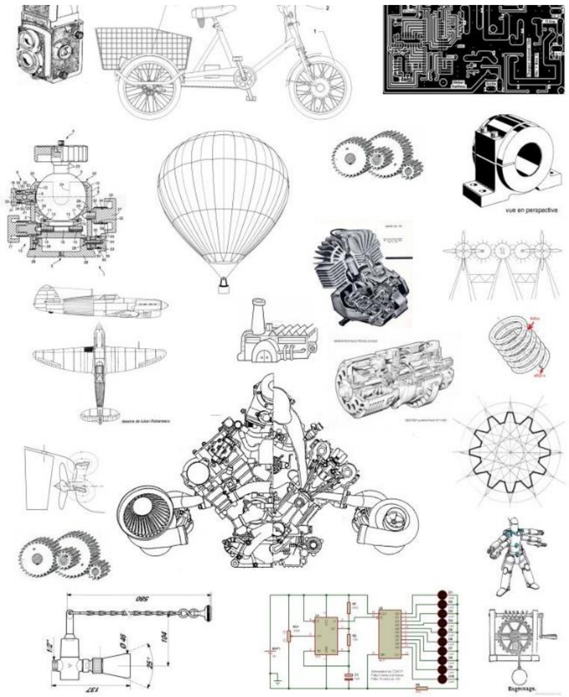

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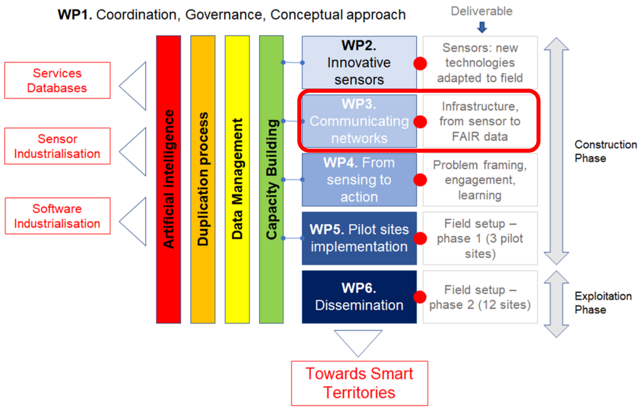

What should we develop in WP3 ?

« From sensors to Cloud »

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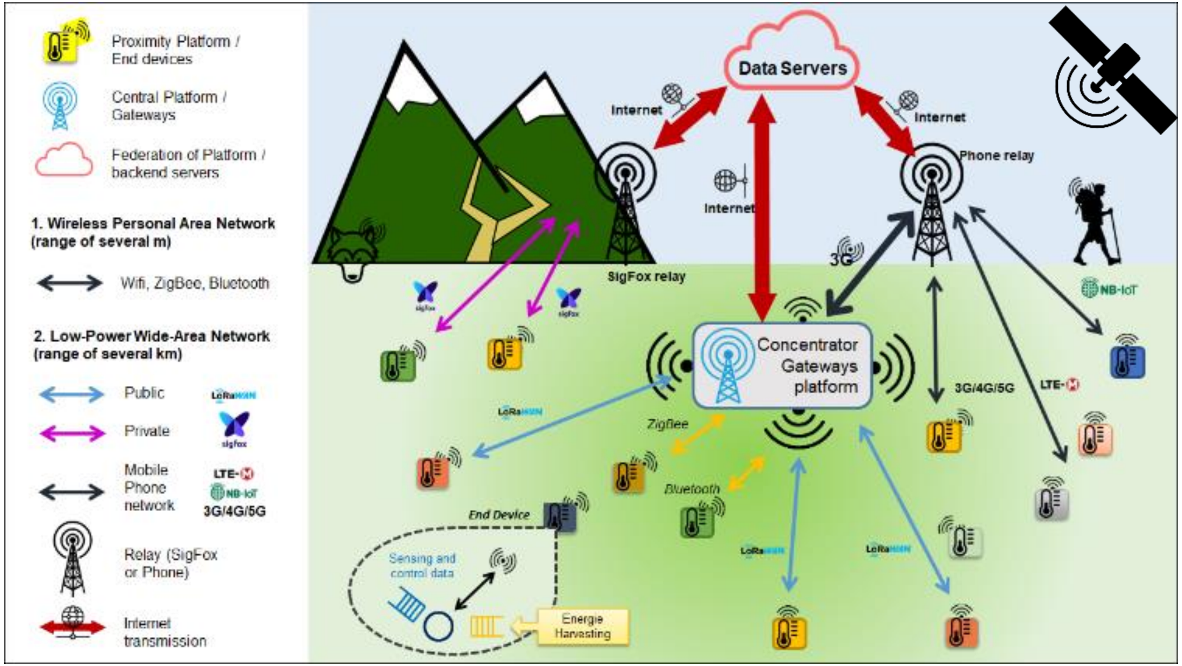
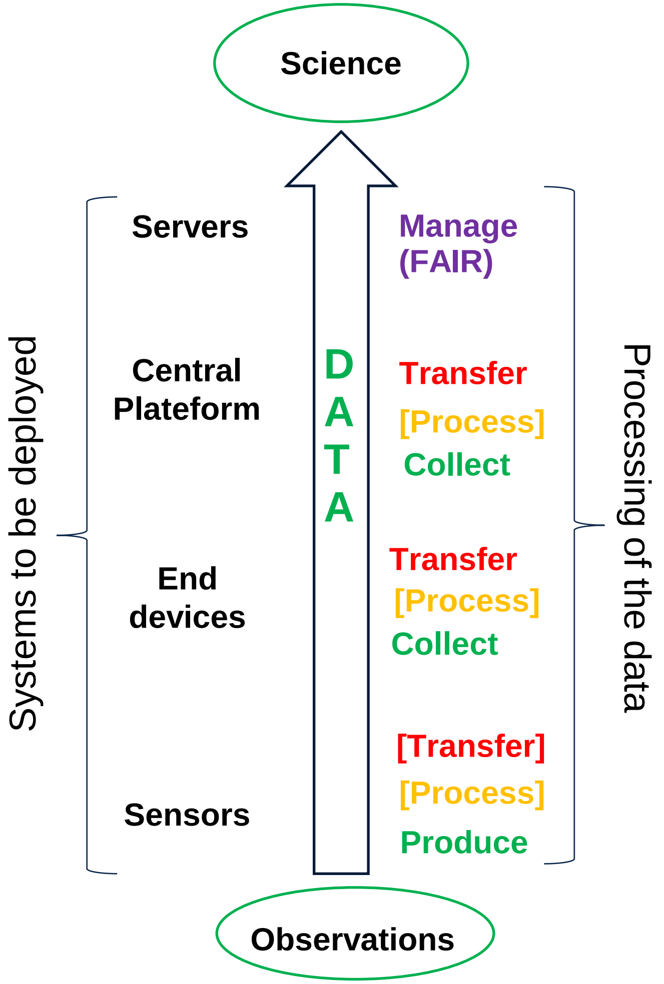
From Field Measurements to Science
→ From Sensors to Cloud

WP3

Dense and scalable networks of heterogeneous sensors





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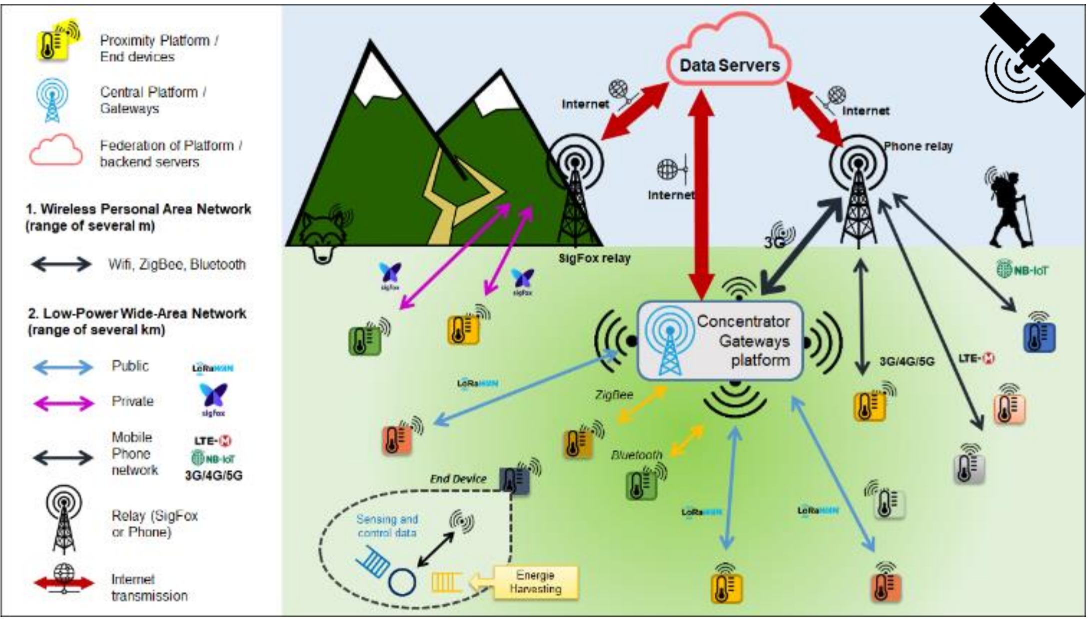
From Field Measurements to Science
→ From Sensors to Cloud

WP3

Dense and scalable networks of heterogeneous sensors



Requirements:

→ Deployment of relevant communication technologies to meet the **needs** and **constraints** of **each sensor** and each **location** (WPAN, LPWAN)

→ Multi-protocol **central platform** to aggregate data

→ **Energy harvesting** when needed and possible

→ **Scalable** infrastructure

A wide variety of sensors, technologies, use-cases … to be addressed !

(the challenge of the data management not presented here)

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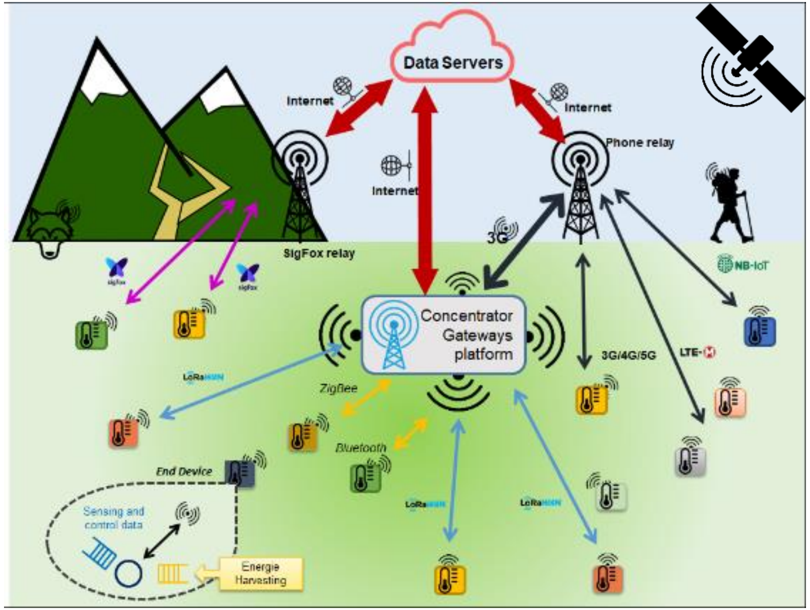
From Field Measurements to Science
→ From Sensors to Cloud



Key challenges (1):

→ **Collect all the data** (or almost) produced by sensors
- suitable hardware (wired or wireless interfaces)
- suitable software (specific drivers)

→ **Transfer data** whatever the **location** of the sensor

→ **Ensure a high Quality of Service**

→ **Limit the maintenance needs**: autonomy > 6 months
- Limit the transmission time
- Implement energy harvesting systems
- Design reliable systems

→ **Process data** as soon as possible (only relevant data)

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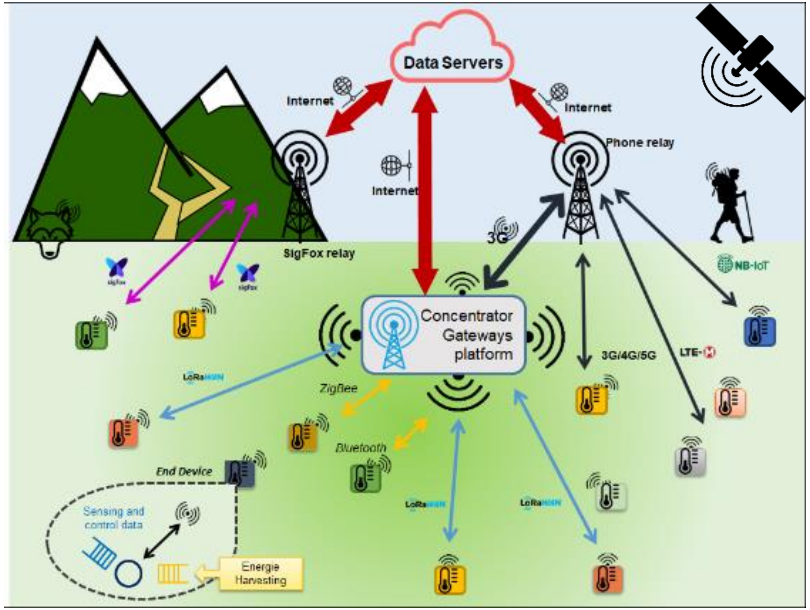
From Field Measurements to Science
→ From Sensors to Cloud



Key challenges (2):

→ **Low cost** (considering the time of life of systems)

- **High durability** (repairability)
- **Upgradability** (new needs, new techno…)

→ **Socially** approved

→ **Accessibility of the systems**

- DIY
- easy to use, tutorial, tech. assistance, …

→ **Low environmental impact** (small, light, discrete, recyclable…)

Tradeoffs to be made !!

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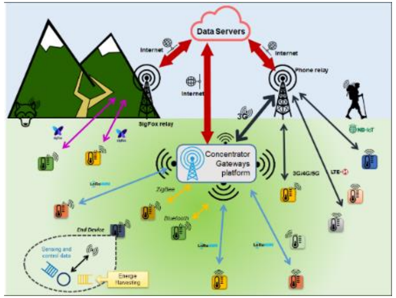
major part of the budget dedicated to manufacturing

TF meeting @St-Jacut in 2022



Who will the « designers » ?

N.B.: Not “builders” because major part of the budget dedicated to manufacturing

Project teams involved in WP3

Terra Forma gathers variety of complementary expertise

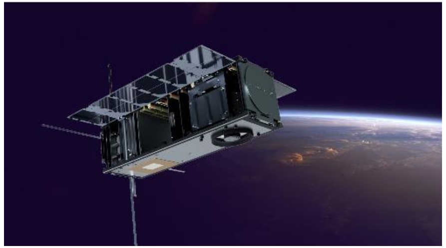
BEYLOT André-Luc
SARRAMIA David
DONSEZ Didier
PIERRE Guillaume
KACIMI Rahim
ROYER Laurent
IRAIN Malik
FREICHEY Matthieu
LE GENTIL Mickael
AMAROUCHE Nadir
CHARADE Olivier
SENTIEYES Olivier
VANDAELE Richard
THIEBOLT Francois

N.B.: Close links with education

Université de Grenoble-Alpes (UGA)
LIG-CNRS laboratory

Skills:

- **LpWAN technologies** (IoT satellite, LoRa, …)
- **RTK over LoRaWAN**
- AI – Tiny ML
- Programming/use of large number of end devices



Cubesat mission

WildCount:Recognizing and counting the presence of humans and animals

Connected groundhog cage

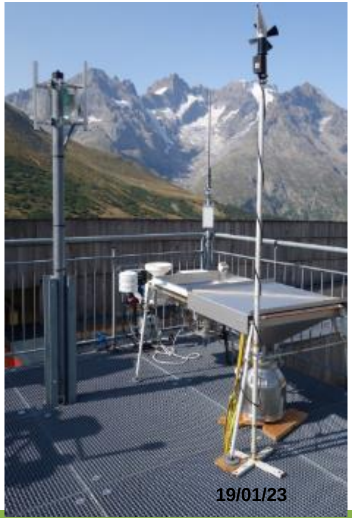
Developments & Experimentations

- ThingSat project
- Counting/recognition of animals – IA for birdsong
- Air Quality Station

Air quality station

OpenCollar (LR1110)

Station LORA station in Alpes



Université de Rennes 1
IRISA laboratory

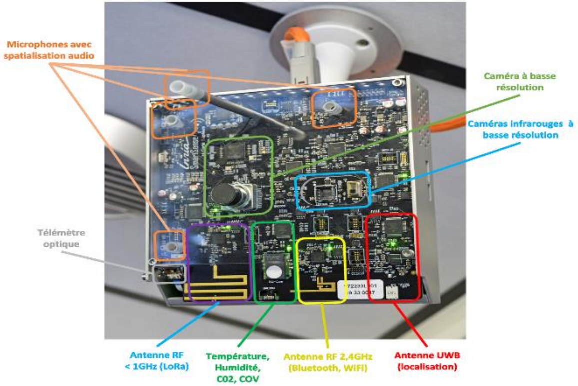
Skills:

- **LPWAN** nodes
  - Adaptive architectures and protocols
- Energy **harvesting** and **management**
  - Model-based and model-free managers (Fuzzyman, RLman)
- **Wake-up** radio
- Radio-Frequency security
- **Fog** computing

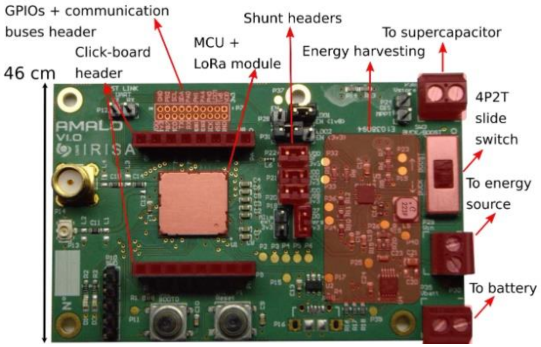
The FogGuru hardware platform

Developments & Experimentations

- Fog computing platform (FogGuru)
- Autonomous LoRa sensor board (AMALO) with power harvesting, energy storage and management
- Multi-sensors network (SmartSense)



SmartSense : multi-sensors network



AMALO: adaptative LoRa nodes

PowWow : energy autonomous nodes

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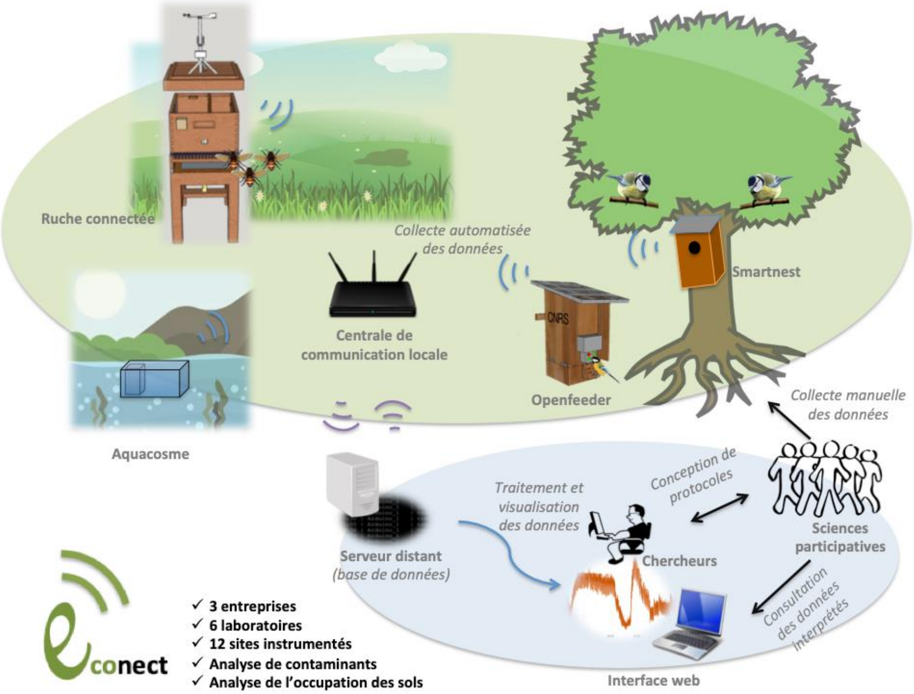
Institut National Polytechnique de Toulouse
IRIT-CNRS laboratory

Skills:

- **LpWAN** technologies
- **Multi-technology** IoT in-situ central communication platform

Developments & Experimentations

- Econect: Connected sensors for monitoring ecosystems and biodiversity



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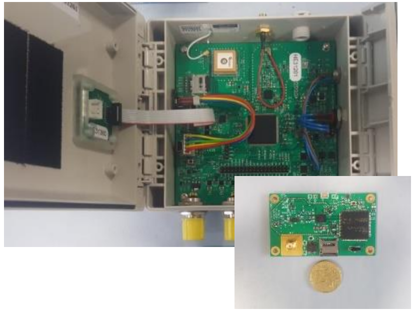
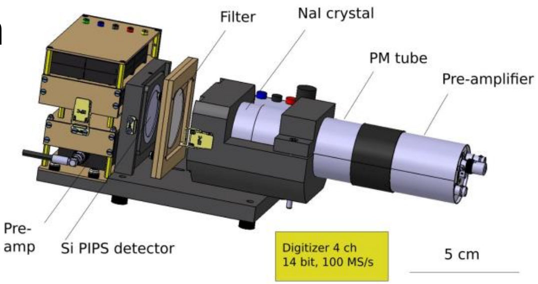
Université de Clermont Auvergne (UCA)
LPC-CNRS laboratory

Developments

SoLo and mini-SoLo





Radon **A**nalysis on **V**olcanoes with **I**n-situ **O**bservations of short-**L**ived **I**sotopes (RAVIOLI)

Experimentations

- 6 sites in Auvergne (lake, rivers, agr. field, pasture, …)
- Volcanos: Etna, Masaya, Soufrière


Sciences

A Clermont-Ferrand, on surveille... l'Etna

Le volcan sicilien est surveillé désormais depuis l'Auvergne. L'objectif : mieux étudier le rôle du radon, un gaz radioactif, dans les éruptions.

- **Skills:**

- **LoRaWAN private networks** in highly constrained environments
- LoRaWAN generic node (SoLo)
- **Radioactivity** measurement
- **Data Management (CEBA)**
- Management of large collaboration project (HEP programs)

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Division Technique (DT) of INSU-CNRS

Skills:

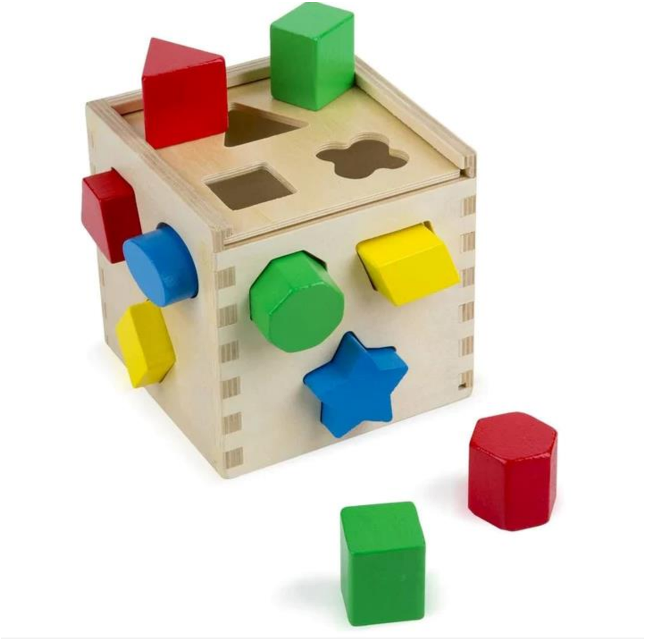
- Technical staff of about 40 p.
- Design and deployment of instruments for **hostil environments**
- Management of **public tenders** for devices duplication process
- Management of instrument stock

Developments & Experimentations

- Design, test and the french seismologic and geodesic network (RESIF) system; management of contracting for production

From prototype …

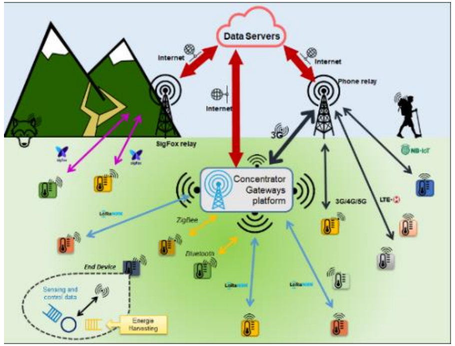
… to industrial system



How will meet the need?

« From sensors to cloud »

From the requirements to the design



- Reminder: a wide variety of sensors, technologies, use-cases … to be addressed !
- To “connect” all the sensors to cloud, we should consider (at least) **3 options**:

a single **generic** system

adapted for almost all the needs

a **modular** system

configurable for each need

specific devices

adapted for each need

Examples ➔

node LoRa « SoLo »

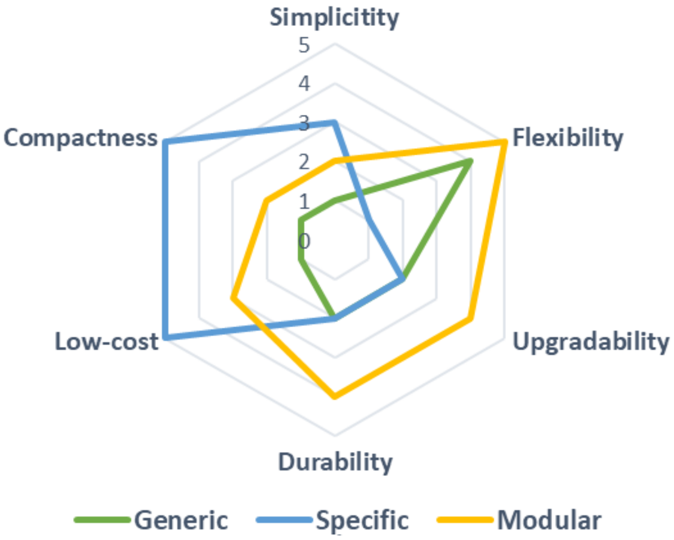
VME bus

Arduino board

node « mini-SoLo »

From the requirements to the design

- Here, a fast assessment of the 3 options (**Generic**, **Specific**, **Modular**)
- 6 criteria considered:
  - **Simplicity**: ease of design, of building and use
  - **Flexibility**: capacity to adapt to new needs
  - **Upgradability**: possibility of upgrade
  - **Durability**: system designed for a long service life
  - **Low-Cost:** effective cost over the lifetime
  - **Compactness:** in-situ “discretion” of the system



➔ **Modular** option seems to be **a « good » tradeoff**, but

→ need to define and fix upstream the software and hardware architecture

→ need to define and adopt a minimal of standards

➔ **option to be investigated (dedicated working group on standardization)**

➔ **In any case, need to share the know-how/skills and technical solutions inside community working on research for environment**

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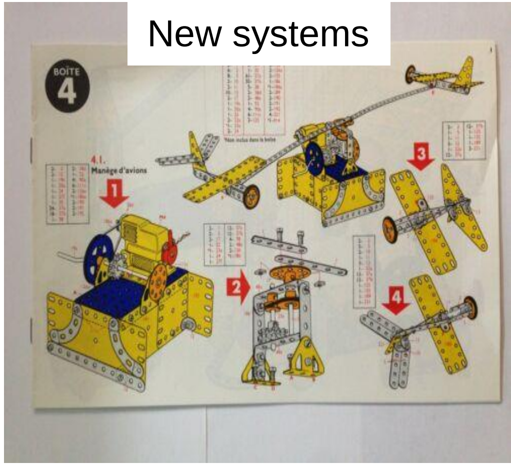
ResCap'E: a catalog of technical solutions **from** and **for** the environmental research community

Know-how

- Electronics
- Smart systems
- Integration, packaging
- On-site deployment and use
- Energy Harvesting
- Measurement in environment

ResCap'E

New systems



Developed systems

- Power supply
- Control
- Embedded Memories
- Complete Instruments
- Packages
- Communication
- Sensors
- Localisation

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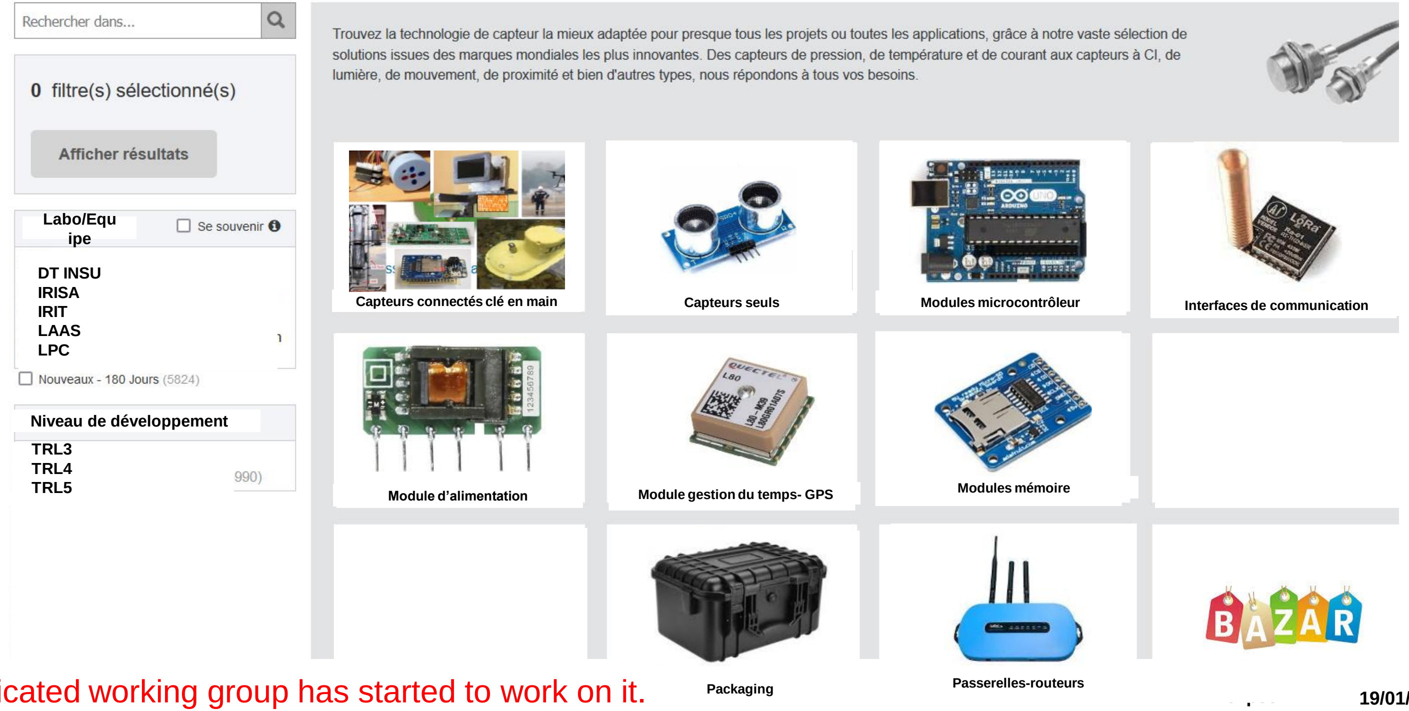
ResCap'E

- **Online** catalog sharing **technical solutions**, well documented, evaluated, improved, … but also **knowledges**
- From complete systems (turnkey instruments) to building blocks
- Something like this web page:



A dedicated working group has started to work on it.

Conclusion & perspectives

« From sensors to cloud »

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Conclusion & perspectives

- Terra Forma is a challenging project which proposes "*the implementation of an **observatory** involving the co-location of a **large number of in situ measurements** to follow the trajectory of **socio-ecosystems**, through a **multi-messenger** approach*" *(L.Longuevergne, project leader).*
- An in-situ infrastructure to collect and transmit the data of the sensors must be designed and deployed.
- Terra Forma has brought together numbers of academic experts in the field of IoT for environment. They provide to TF many technological solutions to be used or to be developed to meet the heterogeneous needs.
- We have the ambition to built the first national on-line catalog gathering all the academic technical developments and skills in the filed of "Instrumentation for Environment".
- The next months will be important to define if some standards can or should be defined to the interoperability of the systems at different scales.
- **Thanks to the Eclipse community for sharing innovative technological solutions to overcome the challenges of Terra Forma, and to give us collaboration opportunities**

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Laboratoires impliqués : CARRTEL, CEBC, CEFE, Centre de Géosciences, CERFE, CESBIO, Chrono-environnement, CRAL, CReSTIC, DT-INSU, Dynafor, ECOBIO, ECOLAB, EVS, GET, GR, GSMA, HABITER UR, IGE, IM2NP, IPAG, IPGP, IRISA, IRIT, ISM, ISTO, LAAS, LCA, LECA, LEMAR, LHYGES, LIG, LIRMM, LMGE, LPC, LRGP, LIS, RiverLy, SAS, Subatech.

Tutelles et partenaires non académiques : CNRS :INSU, INEE, INSIS, IN2P3, INP, INS2I, INSHS, INSB.**Autres organismes de recherche** : IRD, INRAE, IPGP. **Ecole d'ingénieur** : Mines ParisTech. **Universités** : Grenoble, Savoie-Mont-Blanc, Toulouse et Toulouse INP, Rennes, Clermont-Auvergne, Montpellier, Reims, Toulon, Franche Comté, Orléans, Strasbourg, Aix Marseille.**EPIC**: INERIS. **PME**: Extralab

Soutiens: CNES, OFB, BRGM, Agence de l'eau Loire Bretagne, Réseau RECOTOX, l'observatoire du sol vivant, Institut Carnot Eau & Environnement, Groupes Régionaux des experts du climat, Régions, Office régionales de la biodiversité, Fondation François Sommer

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BACKUP SLIDE

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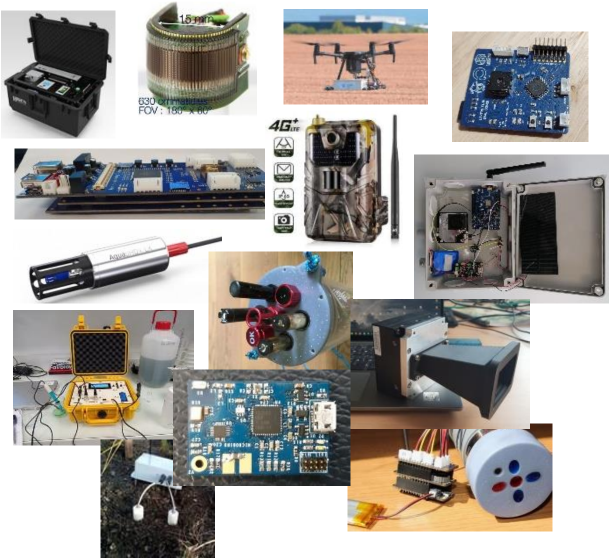
WP2: development of Innovative sensors

Principaux dévelopements	Livrables et nouvelles opportunités
WP2.1 Au-delà des couleurs	Caméra hyperspectrale **haute résolution** + **IA**, Etat des systèmes intégratifs (végétation, rivières), **de la diversité fonctionnelle au fonctionnement des écosystèmes**
WP2.2 Sonde multiparamètre	**Sonde flux de matière bas cout**: débit, Chl-a turbidité, O2, pH, CO2, Nitrate, matière organique dissoute. **Bassins de tête et variabilité**
WP2.3 Métabolisme des rivières	**Isotopes du carbone in situ,** gaz dissous inertes et réactifs, **origine du carbone inorganique dissous**
WP2.4 Bioaccumulation des contaminants	Intégrateurs **rapides et contrôlés large spectre** pour métaux trace, pesticides, résidus, contaminants émergents …
WP2.5 Gaz à effet de serre - flux d'échanges	**Cartographie haute résolution des** flux de CO2, CH4, H20 **embarqué sous drone**.
WP2.6 Biologging	**Colliers GPS/accéléromètre**, capteurs miniatures, de la **position au comportement**
WP2.7 Capteurs biogéochimiques	**Sondes de suivi de l'activité microbiologique**, spatialisation par hydrogéophysique.
WP2.8 Pièges audio-video	Pièges audio/vidéo, **AI embarquée** avec **identification en ligne.**



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