The **M**auna Kea **S**pectroscopic **E**xplorer

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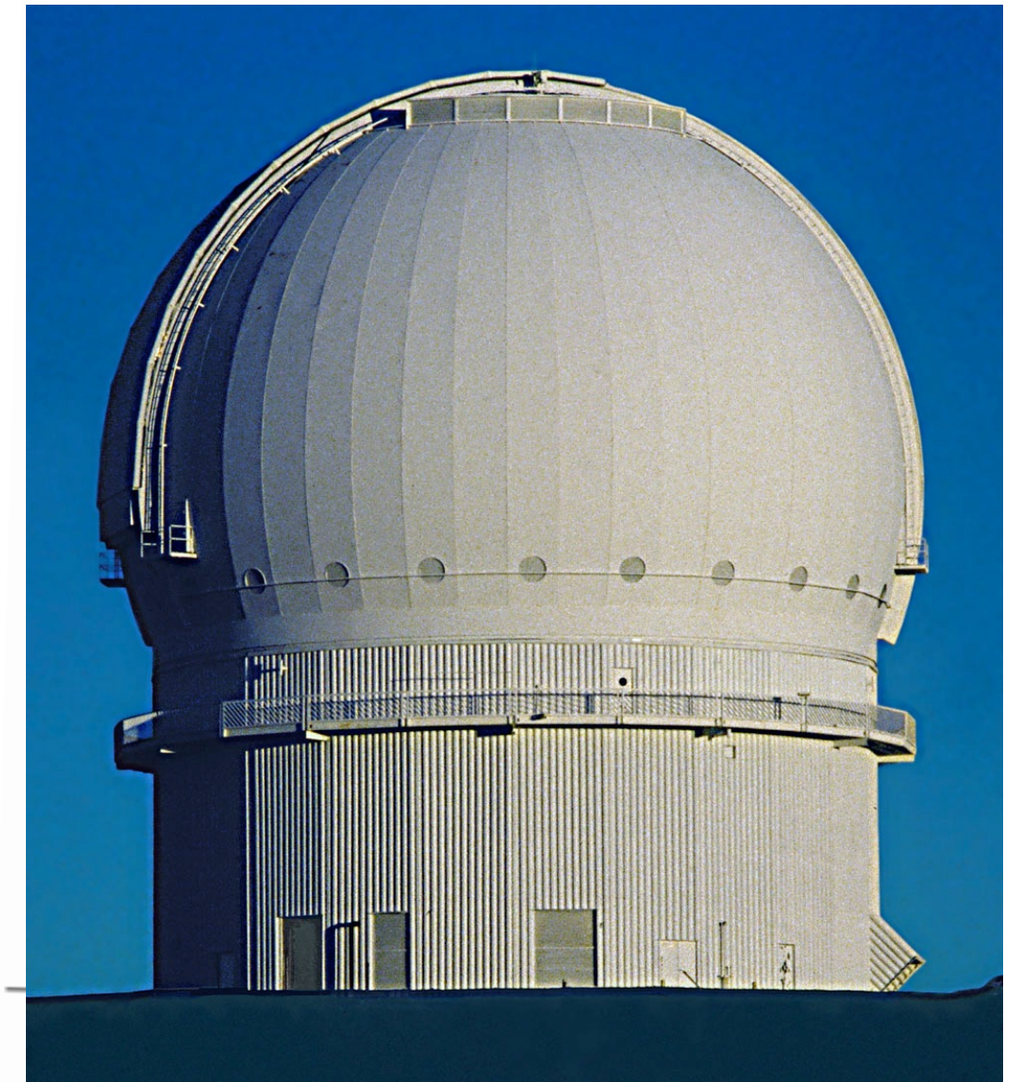
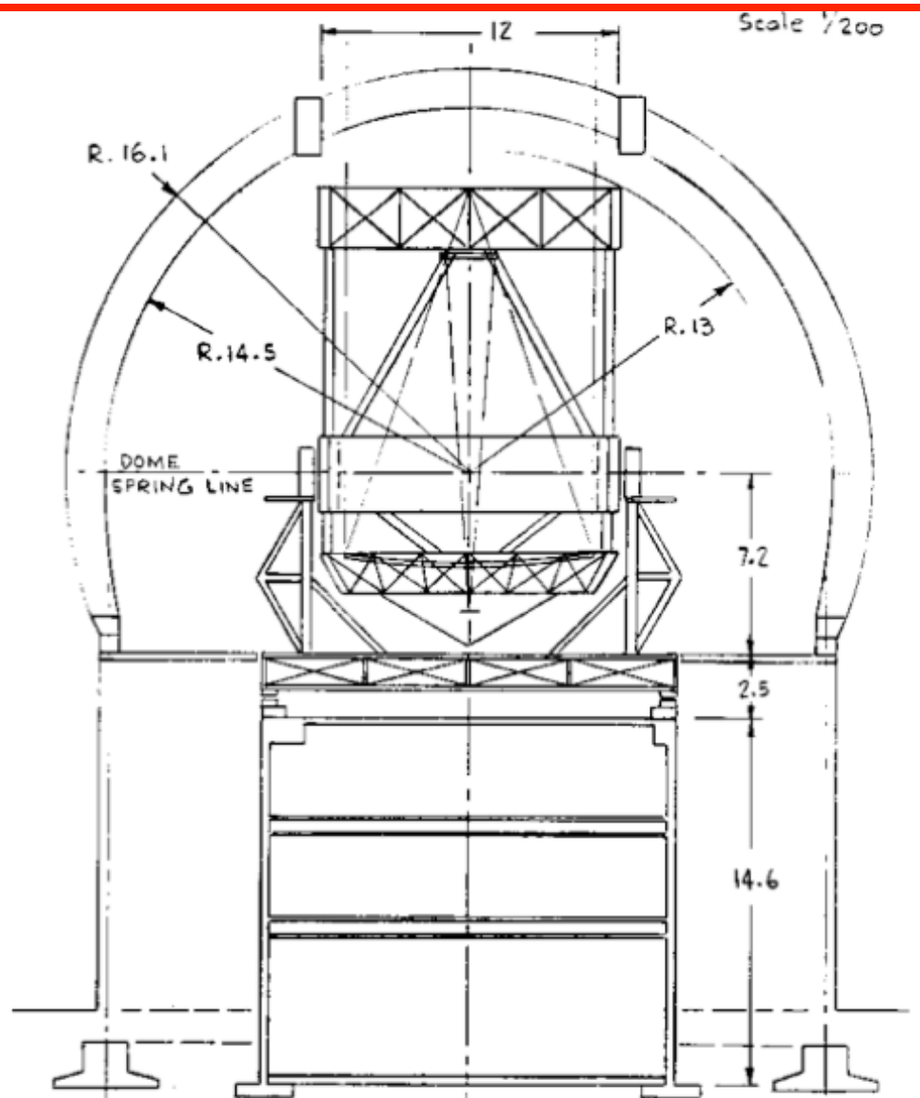
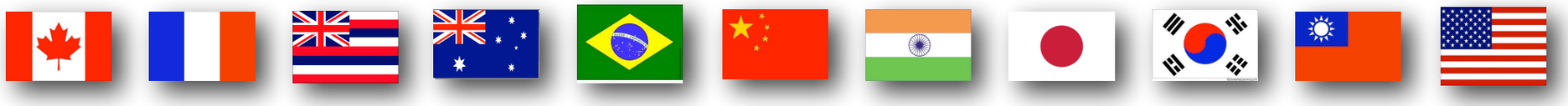
The “Next Generation CFHT” original concept

Create a new and expanded partnership to:

1. replace the present 3.6m primary mirror with a 10m-class (segmented) mirror, mounted on the existing pier.
2. install a **dedicated** wide-field (1.5 deg^2) multi-object spectrograph that can simultaneously collect spectra for >3000 sources.







With thanks to the Feasibility Study science team

- ~60 scientists from Canada, ***France***, and Hawaii, as well as Australia, Brazil, China, India, Japan, South Korea, Taiwan, USA.
- 10 Science Working Groups formed, 2011 - 2012

1. Exoplanets
Magali Deleuil (Lab. d'Astrophysique de Marseille, France)
Francois Bouchy (IAP, France)
Ernst de Mooij (Toronto, Canada)
Norio Narita (NAOJ, Japan)

2. The Interstellar Medium
Rosine Lallement (GEPI/Observatoire de Paris, France)
Patrick Boissé (Institut d'Astrophysique de Paris, France)
Ryan Ransom (Okanagan College, DRA, Canada)

3. Stars and Stellar Astrophysics
Kim Venn (University of Victoria, Canada)
Katia Cuhna (NOAO, USA)
Patrick Dufour (Montreal, Canada)
Zhanwen Han (Yunnan Observatory, China)
Chiaki Kobayashi (ANU, Australia)
Rolf-Peter Kudritzki (IfA, Hawaii, USA)
Else Starkenburg (Victoria, Canada)

4. Milky Way Structure and Stellar Populations
Piercarlo Bonifacio (GEPI, France)
Nobou Arimoto(NOAJ, Japan)
Ken Freeman (ANU, Australia)
Bacham Eswar Reddy (IIA, India)
Sivarani Thirupathi (IIA, India)

5. The Local Group
Alan McConnachie (HIA, Canada)
Andrew Cole (Tasmania, Australia)
Rodrigo Ibata (Strasbourg, France)
Pascale Jablonka (Observatoire de Paris, France)
Yang-Shyang Li (KIAA, China)
Nicolas Martin (Strasbourg, France)

6. Nearby Galaxies and Clusters
Michael Hudson (University of Waterloo, Canada)
Richard de Grijs (KIAA, China)
Simon Driver (ICRAR, Australia)
Eric Peng (Peking University, China)
Yen-Ting Lin (IPMU, Japan)

7. Galaxy Evolution
Michael Balogh (University of Waterloo, Canada)
Sebastien Foucaud (NTNU, Taiwan)
Damien Le Borgne (IAP, France)
Karl Glazebrook (Swinburne, Australia)
Lihwai Lin (ASIAA, Taiwan)
Changbom Park (KIAS , South Korea)
Swara Ravindranath (IUCAA, India)
Marcin Sawicki (St. Mary's, Canada)
Luc Simard (HIA, Canada)

8. The Intergalactic Medium
Céline Péroux (Lab. d'Astrophysique de Marseille, France)
James Bolton (Melbourne, Australia)
Sara Ellison (Victoria, Canada)
Raghunanathan Srianand (IUCAA, India)

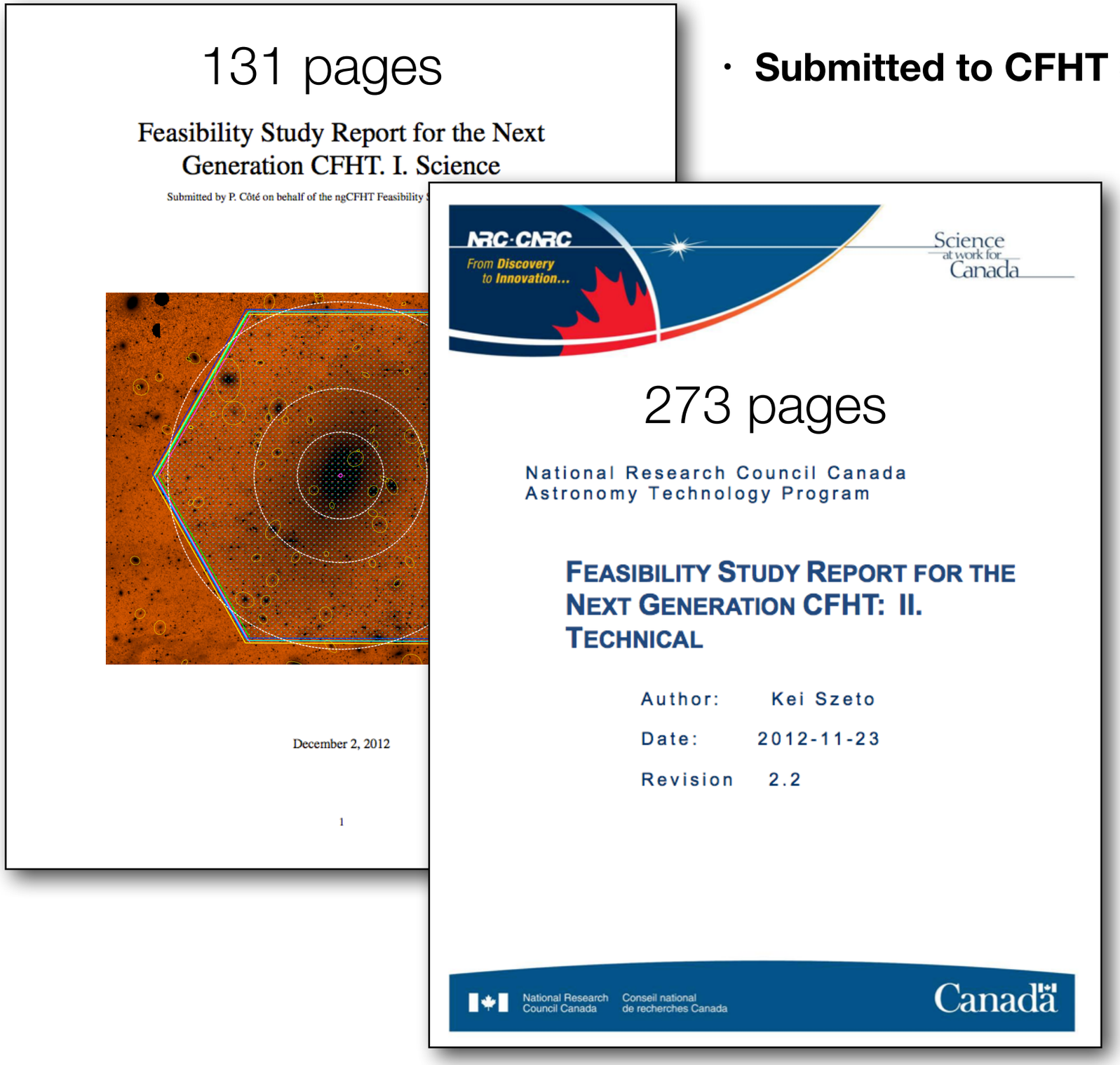
9. QSOs and AGNs
Pat Hall (York University, Canada)
Len Cowie (IfA, Hawaii)
Scott Croom (Sydney, Australia)
John Hutchings (HIA, Canada)
Patrick Petitjean (AIP, France)
Thaisa Storchi-Bergmann (UFRGS, Brazil)
Ting-Gui Wang (USTC, China)
Chris Willott (HIA, Canada)
Jong-Hak Woo (Seoul, South Korea)
Xue-Bing Wu (Peking University, China)

10. Cosmology and Dark Energy
Jean-Paul Kneib (Lab. d'Astrophysique de Marseilles, France)
Carlo Schimd (LAM, France)
Charling Tao (CPPM, France and Tsinghua, China)
Martin Makler (Rio de Janeiro, Brasil)
Keiichi Umetsu (ASIAA, Taiwan)

MSE/ngCFHT Development:

Completed (unsolicited) Feasibility Studies at http://ngcfht.org

See also: http://mse.cfht.hawaii.edu



- **Submitted to CFHT SAC and Board in Fall 2012**

Primary Outcomes

- Redevelopment could utilize the existing pier and building with only minor modifications.
- The conversion would not increase the visual footprint of CFHT on Mauna Kea.
- **No technical "show stoppers" with the telescope, enclosure, spectrograph, fibre-feed system, or operations model.**

MSE development

Board supports proposal in February 2014

Project Office announced in May

Science Team formed (~70 members, ~20 French)

Get in touch if you're interested in joining!

Interim Project Manager: **Rick Murowinski**
Interim Project Scientist: **Alan McConnachie**
Interim Project Engineer: **Derrick Salmon**
(Project Manager and Project Scientist positions being advertised now)

French contact: **Nicolas Martin (**nicolas.martin@astro.unistra.fr**)**
MW, resolved stellar pops survey: **Carine Babusiaux**

Defining concept of MSE

MSE will:

- obtain efficiently very large numbers (>10^6) of low- (R ~ 2 000), moderate- (R ~ 6 500), and high-resolution (R ~ 20 000) spectra
- for faint (20 < g < 24) science targets
- over large areas of the sky (10^3 – 10^4 sq.deg)
- spanning blue/optical to near-IR wavelengths (0.37 – 1.3μm).
- at the highest resolutions, it should have a velocity accuracy of <<1 km/s
- at low resolution, complete wavelength coverage should be possible in a single observation

Unique science cases of MSE stemming from:

- 10 m aperture
- Operation at a range of spectral resolutions
- Dedicated Operations, producing stable, well-calibrated and characterised data
- Long lifetime

Defining elements I: A 10m telescope

Large number of excellent 4-m class efforts underway to provide extreme MOS over wide field of view, e.g.

- WHT/WEAVE, ESO/4MOST, MS-DESI, AAT/HERMES

Need the power of an 10-m to nail key science topics of faint Universe:

- ***intrinsically faint stars***
- ***the distant Galaxy***
- ***low mass galaxies***
- ***the high redshift Universe***

Defining elements II: Range of spectral resolutions

- Multiple resolutions available
  - Low (R~2,000), moderate (R~6,500), and high (R~20,000). Case for R~40,000.
  - In marked contrast to several other instruments/facilities (e.g, MS-DESI, PFS)
- Heavily multiplexed (3,000 fibers for LR, 800 for MR and HR)
- Possibility to use multiple resolutions at once?
- Enables a broad range of science to be addressed, instead of focus on a single science case
- ***Operation throughout lunar cycle ie highly efficient operations***

Defining elements III: Dedicated operations

- Dedicated spectrograph:
  - stability; good, homogeneous calibration
  - enabled by *basic operational philosophy* (cf. SDSS)
  - key science cases require ***very low velocity systematics*** (time domain spectroscopy)
- contrary to i.e. PFS, which shares Subaru with other instruments
  - more limited science cases

Defining elements IV: Long lifetime

- As with all such telescopes with a long life, upgrades/revamps will occur, but it is envisioned that MSE will remain a **spectroscopic telescope**

- MSE is **not** built to address a single mission or to conduct just a single survey

- MSE is built to provide a single, missing, **important set of capabilities** and so provide astronomers with **certain types of astronomical data**; it is **designed to excel at providing these data**; in doing so, MSE enables **a vast range of science cases**

A specialised technical capability, and a general science purpose facility

The Science Case for the Maunakea Spectroscopic Explorer

The Composition and Dynamics of the faint Universe

Understanding the physical properties of the *faint* Universe from inter-stellar to cosmic scales

The origin and diversity of stellar systems

Milky Way archaeology at the earliest times

Galaxy evolution across Cosmic Time

Illuminating the Dark Universe

Space-based Completement

Wide-field Follow-up

ELT Feeder

Budget: results from Feasibility Study (2012 dollars)

Item	Cost ($M)
design and management	10
M1 optics	10
M1 support system	5
wide field corrector	10
software and control	12
25%-30% contingencies on above items	12
removal of telescope and dome	6.6
enclosure pier structural upgrade	2.7
telescope structure	30.8
enclosure	28.1
facility redevelopment & commissioning	10
spectrograph system	76.1
Total	**206.3**

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A need for new partners (Australia, Canada, China, France, India,…)

~35 M$/partner for 7 partners

Schedule

- 3.5-year Construction Proposal
  - at which point then-partners are able to make decision to proceed or otherwise based on results + external factors
- Once decision to proceed is made:
  - ~2 years for release of contracts for final design and build of subsystems
  - ~4–5 years for renewal of CFHT → MSE (construction at summit)
- ***~10 years total (2025)***

The Science Team (2014—2017)

Goals: Develop in detail the science case for the MSE, and put together the technical designs and partnership that will ultimately see this facility being built

What outstanding scientific questions should MSE tackle and how to make it possible.

Science split in 3 major axes:

- The MW and resolved stellar populations — Lead Scientist: Carine Babusiaux
- Nearby and low-redshift galaxies — Lead Scientist: Michael Balogh
- High-redshift galaxies and cosmology — Lead Scientist: Simon Driver

Summary

- The **MSE** will fill what is arguably **the major missing capability in the future world-wide suite of astronomical observing capabilities**, particularly for wide-field studies

- Transformative stand-alone science case on the **Composition and Dynamics of the faint Universe**, from inter-stellar to cosmic distance scales. Accessing the faint Universe is an essential need for stellar, Galactic, and extra-galactic programs

- In France:
  - Strong synergy with Gaia, Euclid, MegaCam Northern Sky Survey,…
  - Large French representation in Science Team
  - Yearly meetings tracking progress (+ hopefully support from PNCG)
  - In prospectives: Participation to Project Office/Study at high priority for medium to long term future projects