Einstein Telescope opportunities: orders, co-development, spin-offs

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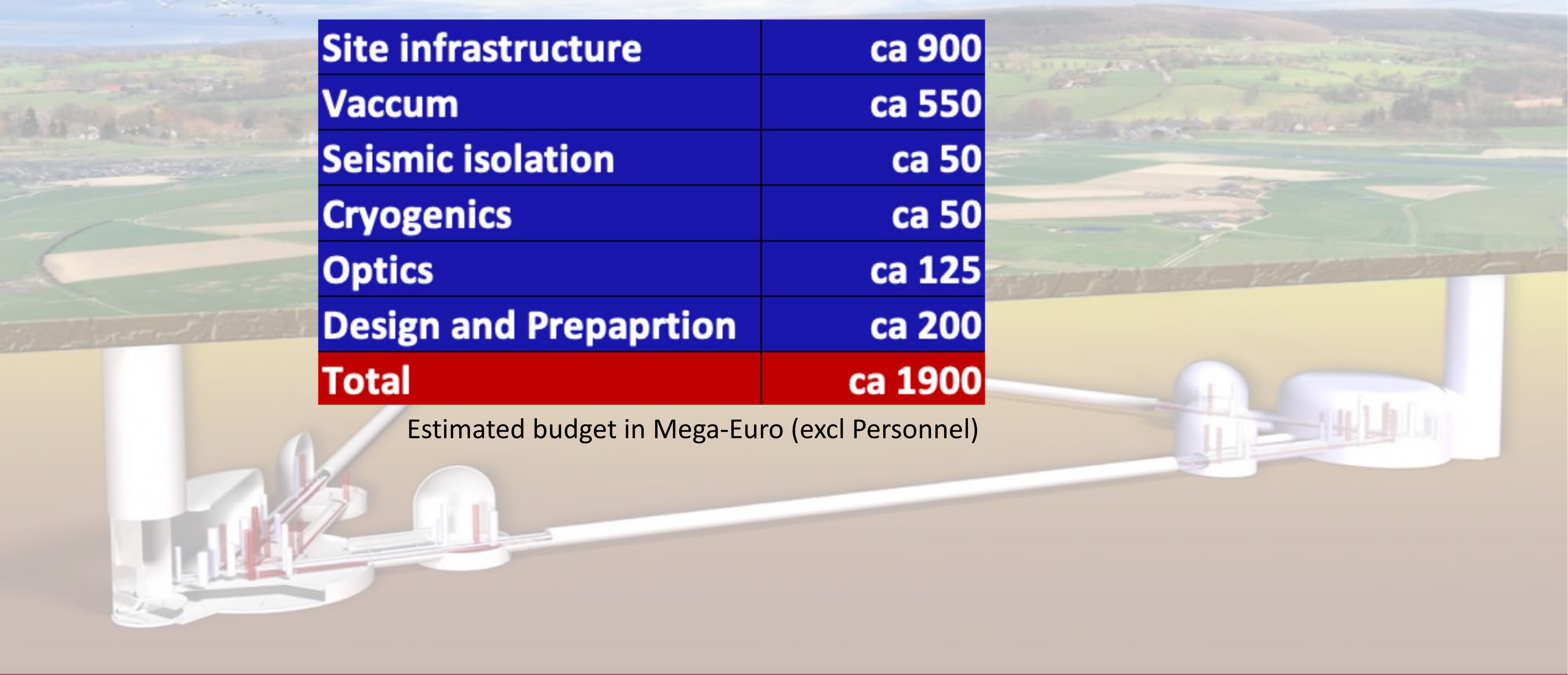
www.etpathfinder.eu / www.einsteintelescope.nl

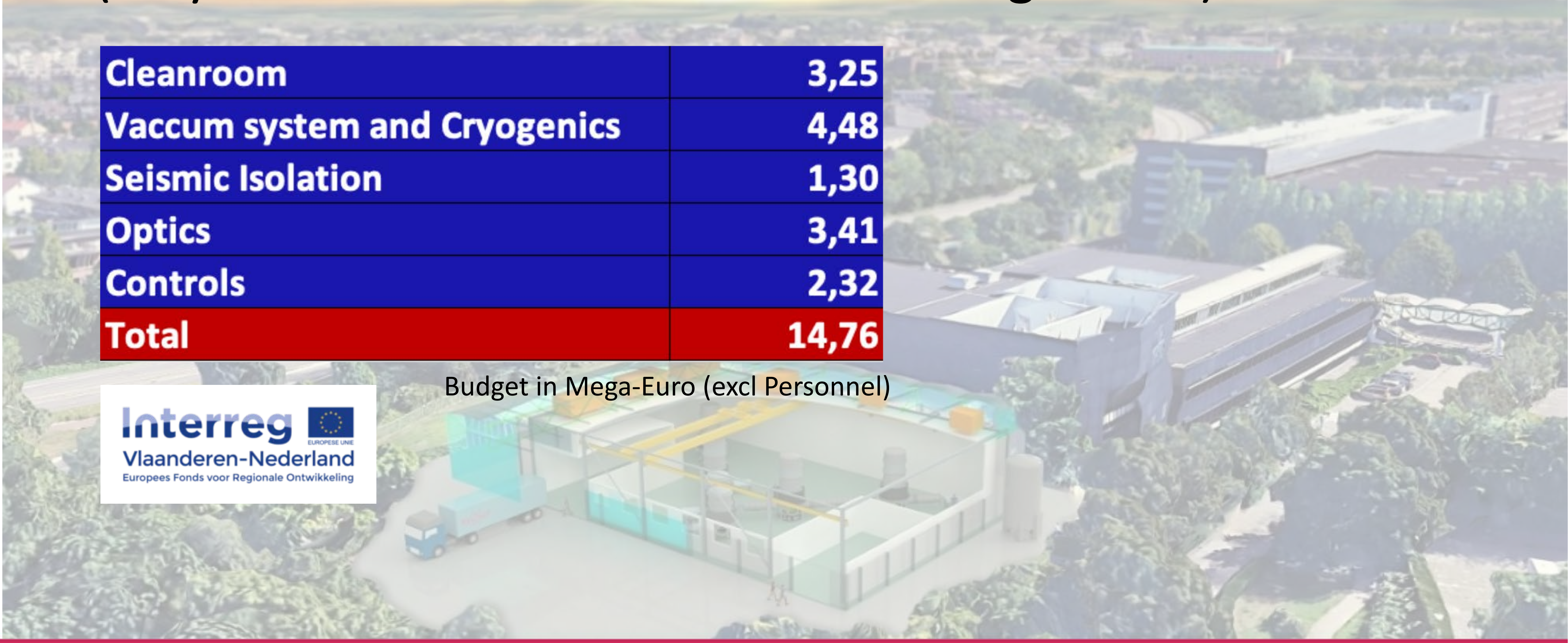
Einstein Telescope



Site infrastructure	ca 900
Vaccum	ca 550
Seismic isolation	ca 50
Cryogenics	ca 50
Optics	ca 125
Design and Prepaprtion	ca 200
Total	**ca 1900**

Estimated budget in Mega-Euro (excl Personnel)

ETpathfinder
(fully funded and under construction right now)



Cleanroom	3,25
Vaccum system and Cryogenics	4,48
Seismic Isolation	1,30
Optics	3,41
Controls	2,32
Total	**14,76**

Budget in Mega-Euro (excl Personnel)

Interreg Vlaanderen-Nederland
Europees Fonds voor Regionale Ontwikkeling
EUROPESE UNIE

Overview

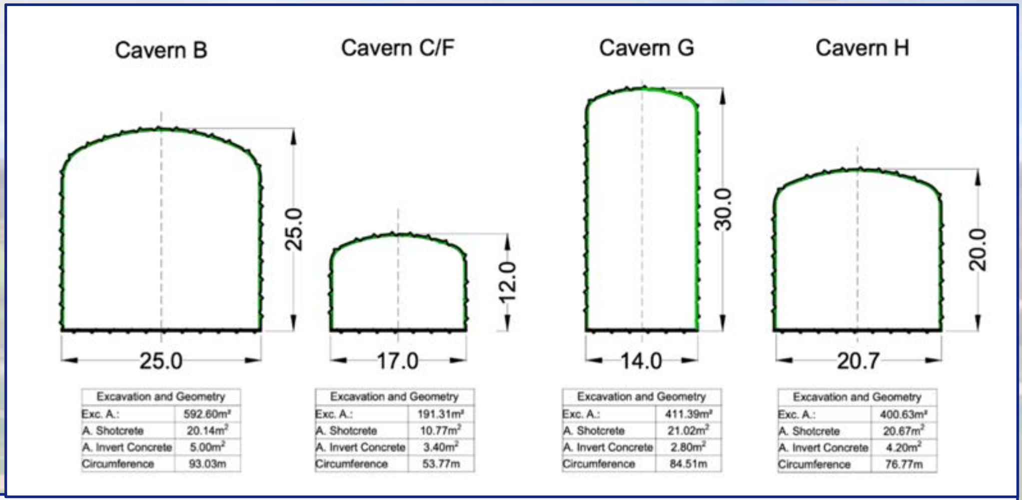
- Orders
- Co-development opportunities
- Examples of previous Spin-offs

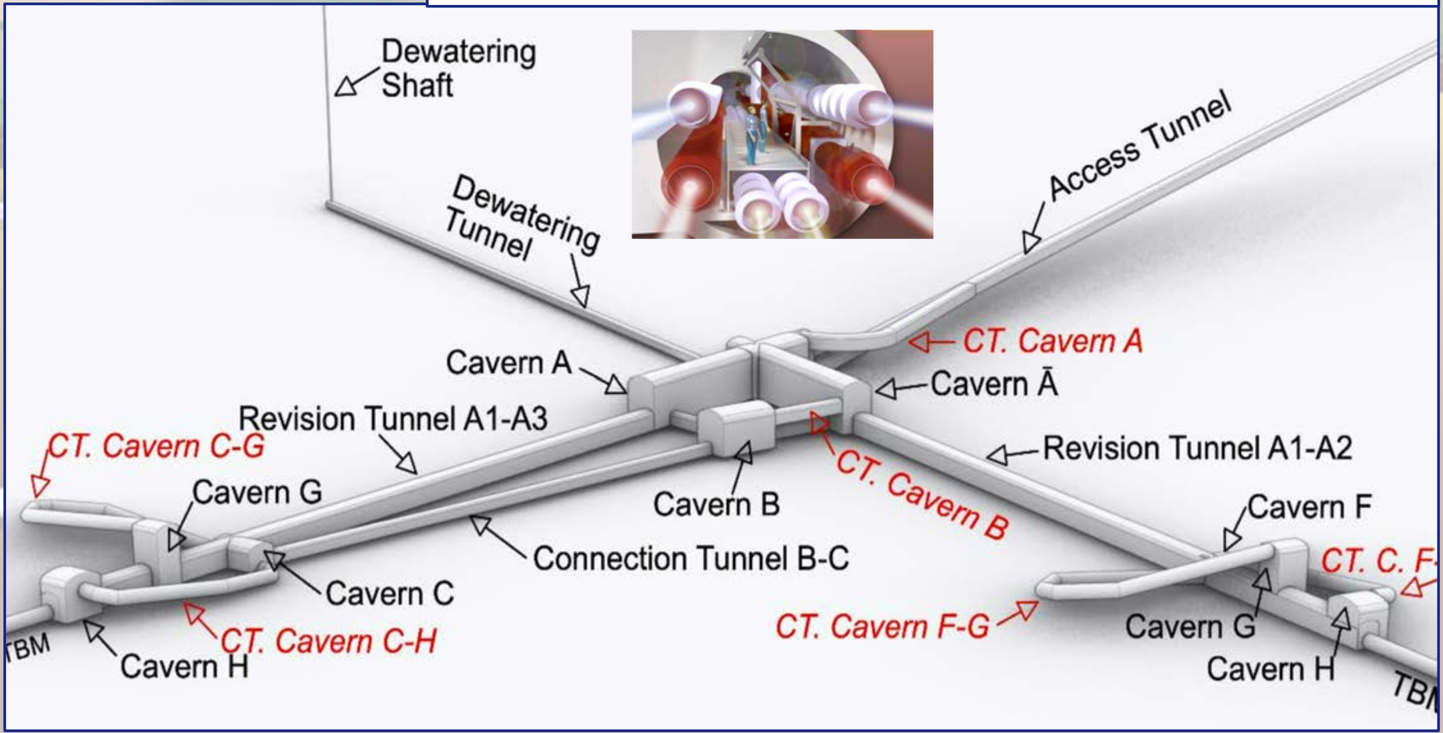
* Note: the following slides are by no means comprehensive or complete and should just be seen as an appetizer to give a rough overview and they are meant as starting point for more in depth discussions (e.g. on the 15th of July or elsewhere).

Underground construction

- Infrastructure for 50+ years
- 30km of tunnels
- Variety of different and huge caverns
- Geological studies and exploration
- Water management
- + surface buildings, roads, etc

Opportunity: Site specific geology and cost optimization of infrastructure





Cleanrooms

- ETpathfinder currently has tender open for a 6000m^3 cleanroom.
- Quality criteria in ETPF tender: low acoustic noise!
- Ultra-low-noise of ventilation and air condition systems even more crucial for ET.

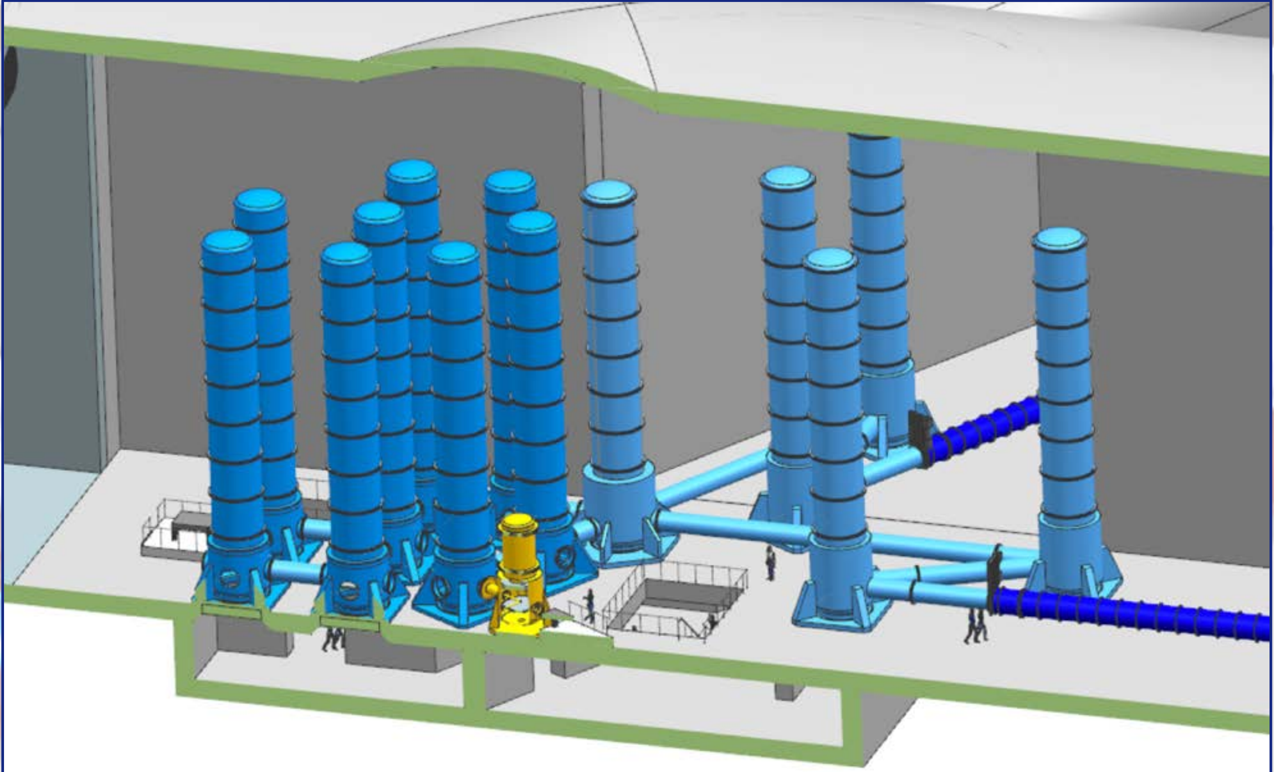
ETpathfinder cleanroom

Opportunity: develop and learn in ETpathfinder to be prepared for ET.


Image credit: Boulby, UK

Vacuum System: ET

- UHV, i.e. <1e-9mbar
- 120+km of vacuum tube (~1m diameter)
- ~100 vacuum towers
- Cleanliness = key requirement!
- Many components: pumps sensors, diagnostics, valves (many and big).



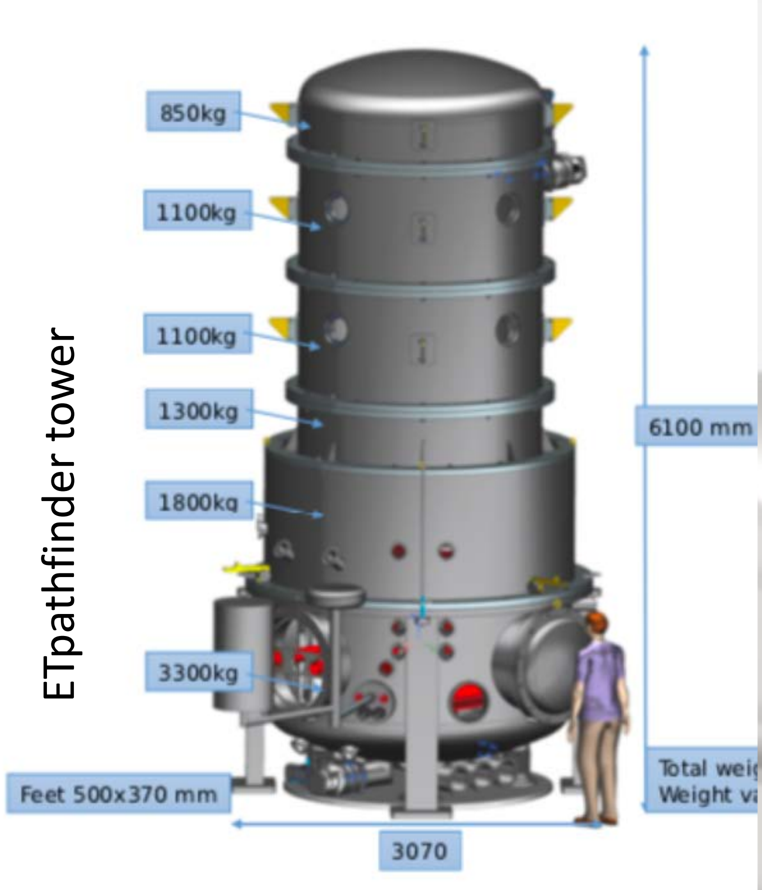
Corner of one ET-LF interferometer

Opportunity Co-development: Identify cost drives and develop smart alternatives

Vacuum System: ETpathfinder

- UHV, 6 towers, short pipes
- Low noise operation (magnetic bearings of turbos etc)
- Prototype facility = frequent venting. Water vapour needs to be managed (moderate baking on regular basis).
- Cleanliness = key requirement!

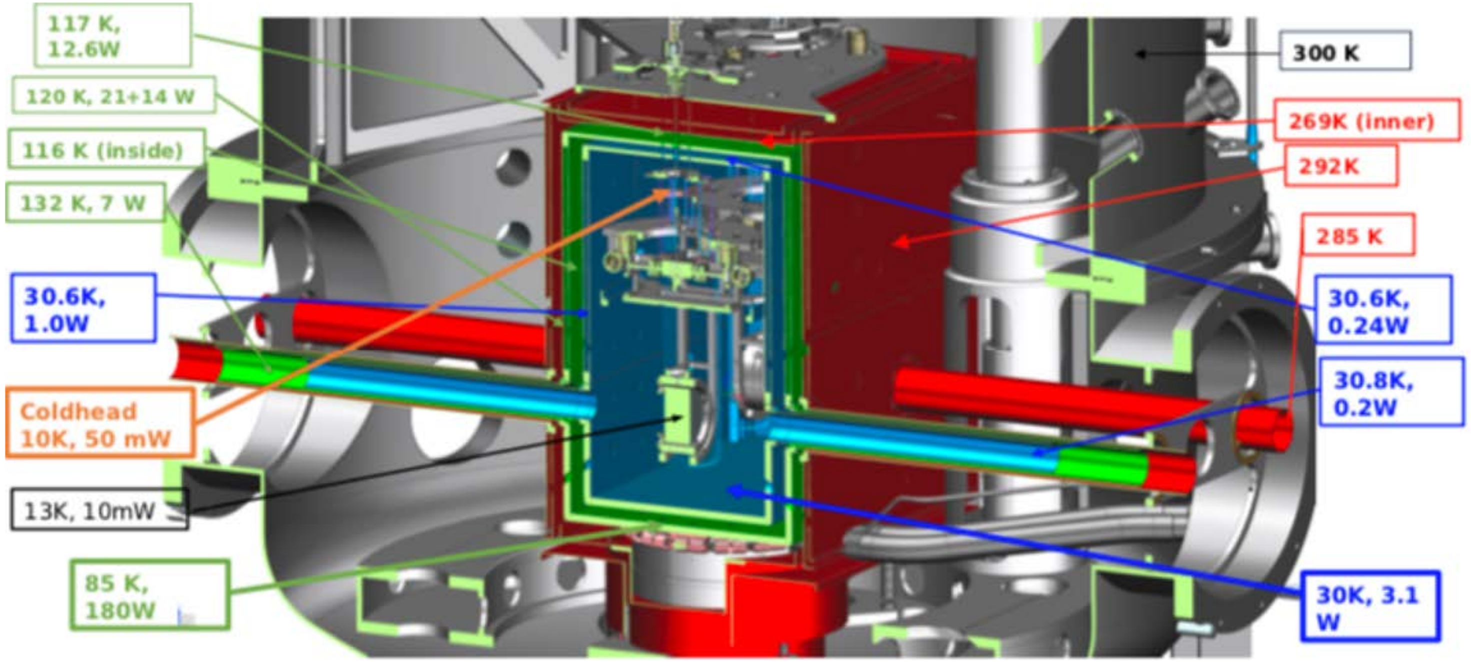
ETpathfinder tower



Opportunity: Tender will be published over the next few months!

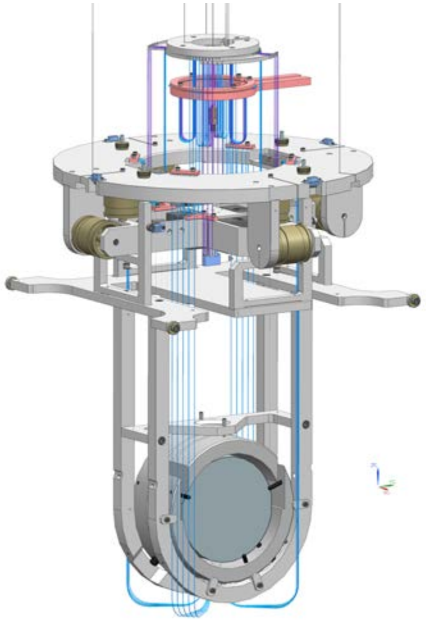
Cryogenics

- Mirrors need to be cooled to cryogenic temperatures (~15K, 123K), without introducing noise, i.e. cooling only possible via thin suspension wires.
- General approaches:
  - Dry system: pulse-tubes. Challenge = reduce and isolate vibrational noise.
  - Sorption coolers (base line in ETpathfider) = more quite, less cooling power.
  - Cryogenic Liquids: LN2, He, HeII. Challenege = avoid bubbling; transfer liquids from surface 300m above the caverns …



ETpathfinder cooling budget

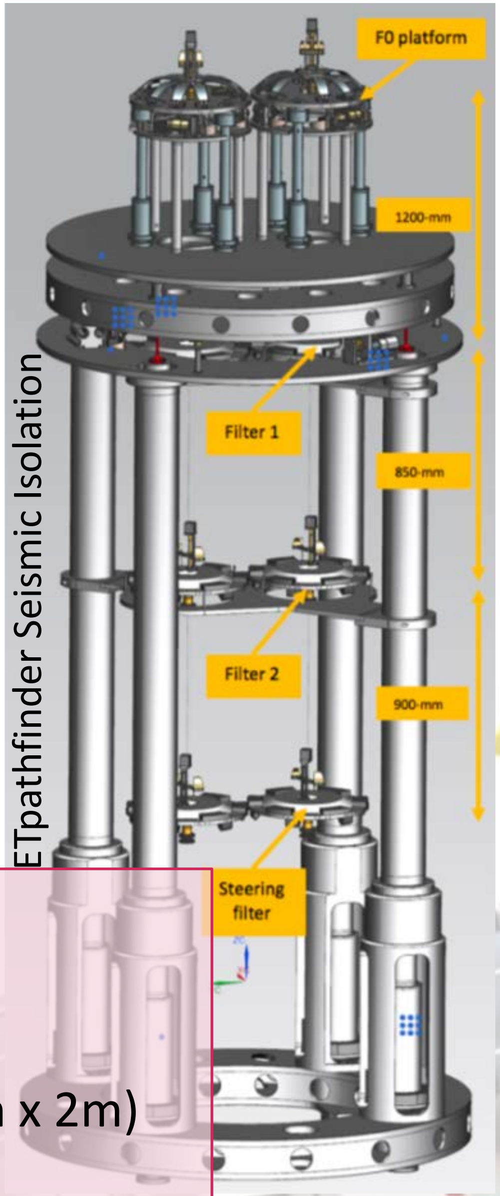
Opportunity for co-development: Low-noise cryo-coolers; heat links; cryogenic infrastructure; etc

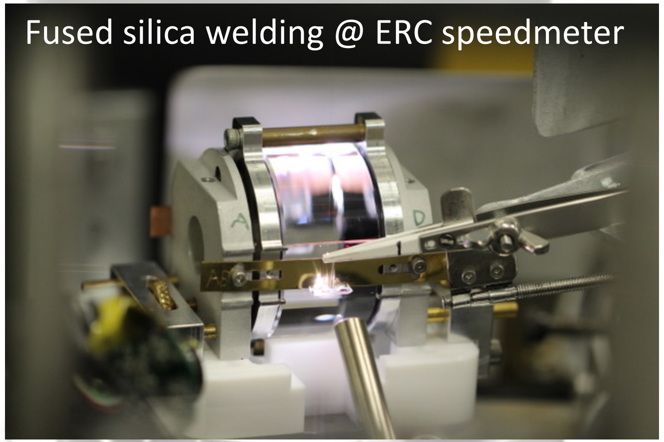


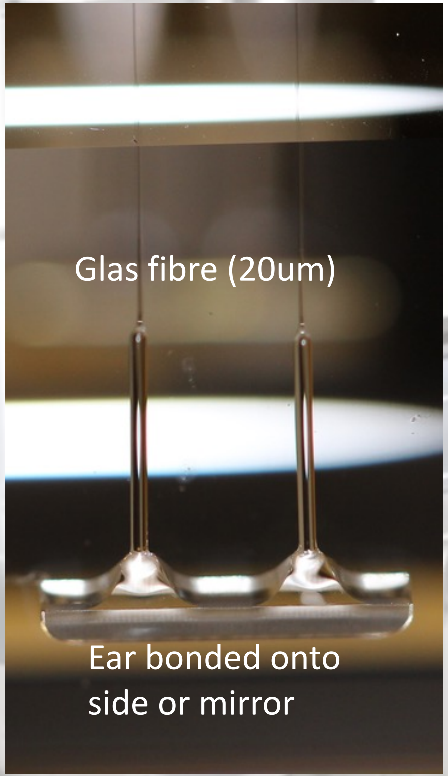
ETpathfinder payload

Vibration Isolations

- Complex custom made systems providing ~10 orders of magnitude suppression at 10Hz
  - Initial stages often active
  - After that all passive (bladesprings and pendula)
- Final suspension stage monolithic, i.e. glass fibres or silicon fibres







Opportunity for co-development:
- Engineering and mechanics optimization;
- sensor and actuator development
- thin silicon fibres (ETPF = 0.7mm x 0.4m; ET = 5mm x 2m)

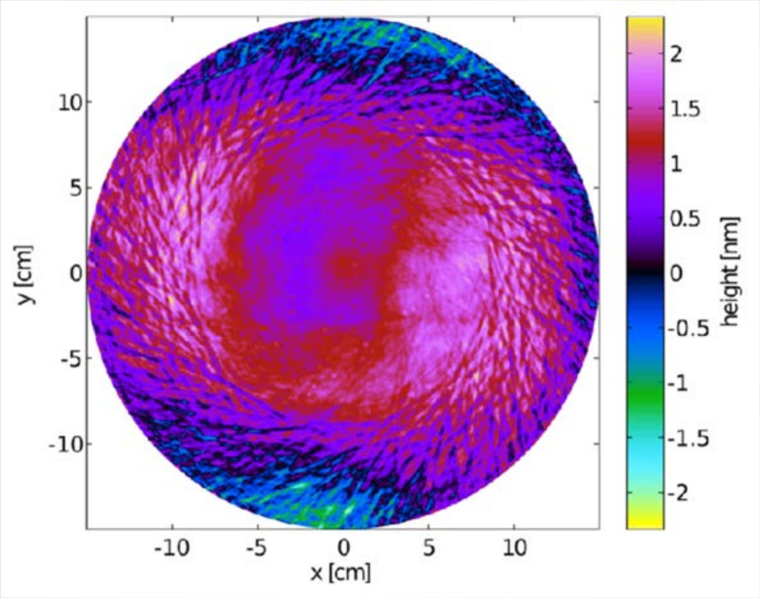
Image Credit: LIGO Laboratory, MIT/Caltech

Optics: Main mirrors

- Huge mirrors (60cm diameter and 200kg weight) with outstanding optical properties:
  - Absorption < 1ppm
  - Roughness <100 pm
  - Flatness <few nm
- Fused silica and Floatzone or mCZ silicon (resistivity >10kOhm cm)
- Low noise thin film coatings

Opportunity for co-development:

- Silicon material in large enough size
- Polishing and metrology
- Optical coatings



Advanced LIGO mirror

Lasers and Optics

- Ultrastable CW lasers and optical components at 1064nm, 1550nm and ~2um.
- Laser bandwidth initially <1kHz and the stabilized to ~mHz
- Several thousand optical elements per interferometer.
- Quantum tricks/technologies like squeezed light and quantum non demolotion

Opportunity for co-development:

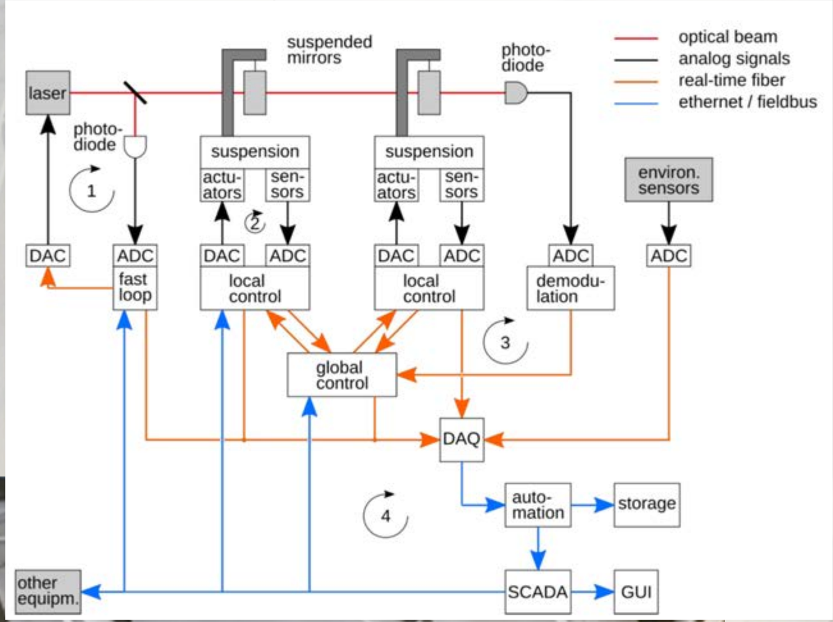
- High quantum efficiency photo detectors for wavelength >1550nm.
- Low loss faraday isolators
- Adaptive optics
- Smart optical design


Advanced LIGO laser

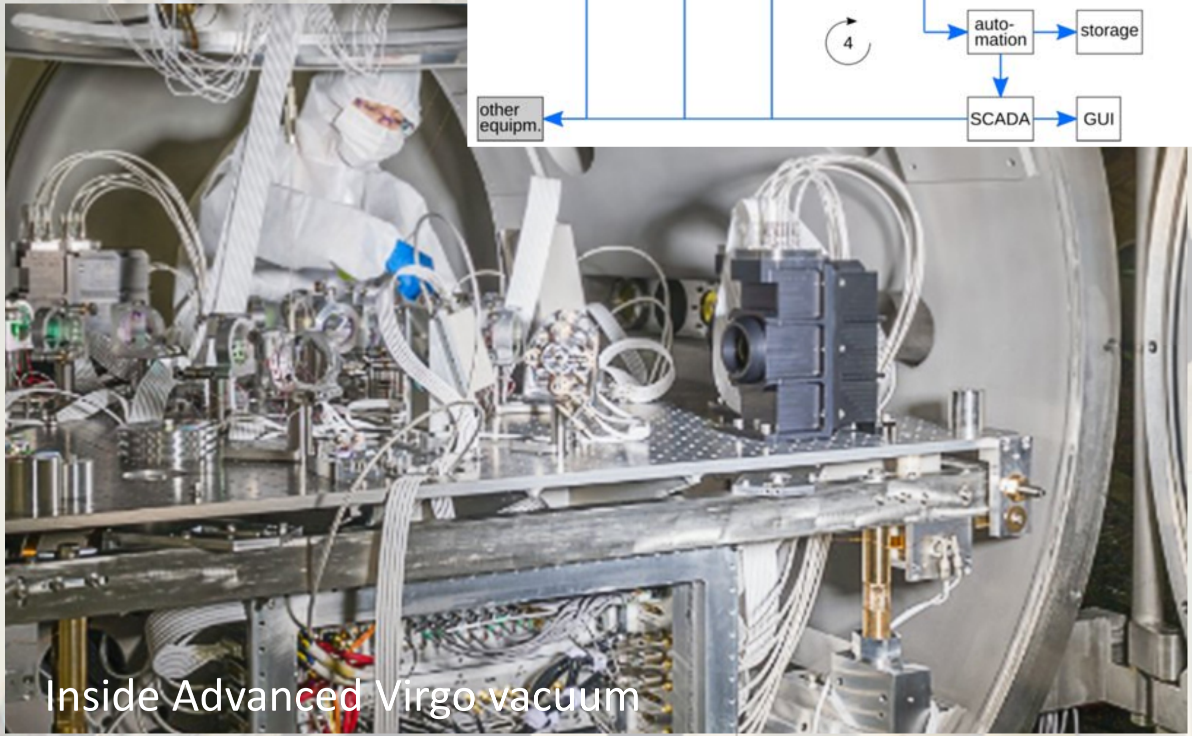

Inside Advanced LIGO vacuum

Controls

- Thousands of sensors, actuators and control loops to keep mirrors with femtometer accuracy at their position and to readout GW signal.
- 2 sides: Hardware and software (smart controls, machine learning, quantum computing (?)…)



Opportunity for co-development:
- In vacuum electronics
- High dynamic range ADC/DAC
- Smart algorithms


Inside Advanced Virgo vacuum

Example of co-development: LISA photodiodes

QPRWG (Quadrant Photo-Receiver Working Group)

Nikhef →	QPD development and testing
SRON →	Program management, housing design
KU Leuven →	Front-end electronics design and development
JAXA →	QPR development and testing
AEI →	TIA, definition and testing of the Optical Metrology System, QPR expertise
ARTEMIS/OCA →	stray-light studies, PR characterisation before and after proton irradiation
UKATC →	PR/OB interfaces
Airbus →	PR/Instrument architecture

Industrial partners

- Bright Photonics
  - ✓ *Design house for Photonic Integrated Circuits*
  - ✓ *Experience with InP & InGaAs materials*

A journey into space!

"Technobis Fibre Technologies, a part of the Technobis Group, of Alkmaar, the Netherlands, has been developing and collaborating in aerospace projects for years. Technobis Fibre currently does so using photonic integrated circuits, which combine many optical elements into one chip and allow modulation and detection of light." Bright Photonics, who designed the chips for Technobis is proud to be part of this journey into space!

PHOTONICS MEDIA photonics.com

Experts added to the team to help with simulations and design

- Smart Photonics
  - ✓ *Device processing of Indium Phosphide based components*
  - ✓ *Zn diffusion*
  - ✓ *Anti-reflection coating*
  - ✓ *Dicing*

Slides courtesy Daniela Pascucci

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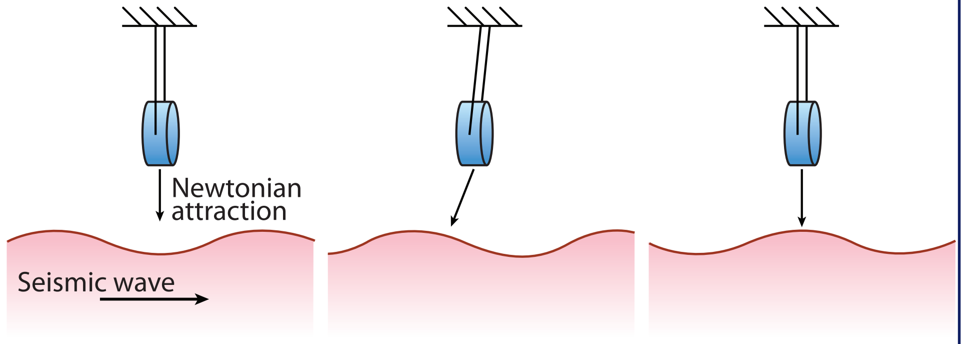
Spin-off Example 1: From ripples in space-time to innovation in seismic imaging

Valorisation opportunity to bring knowledge of seismic noise and measuring techniques to industry application

VIRGO

Nikhef

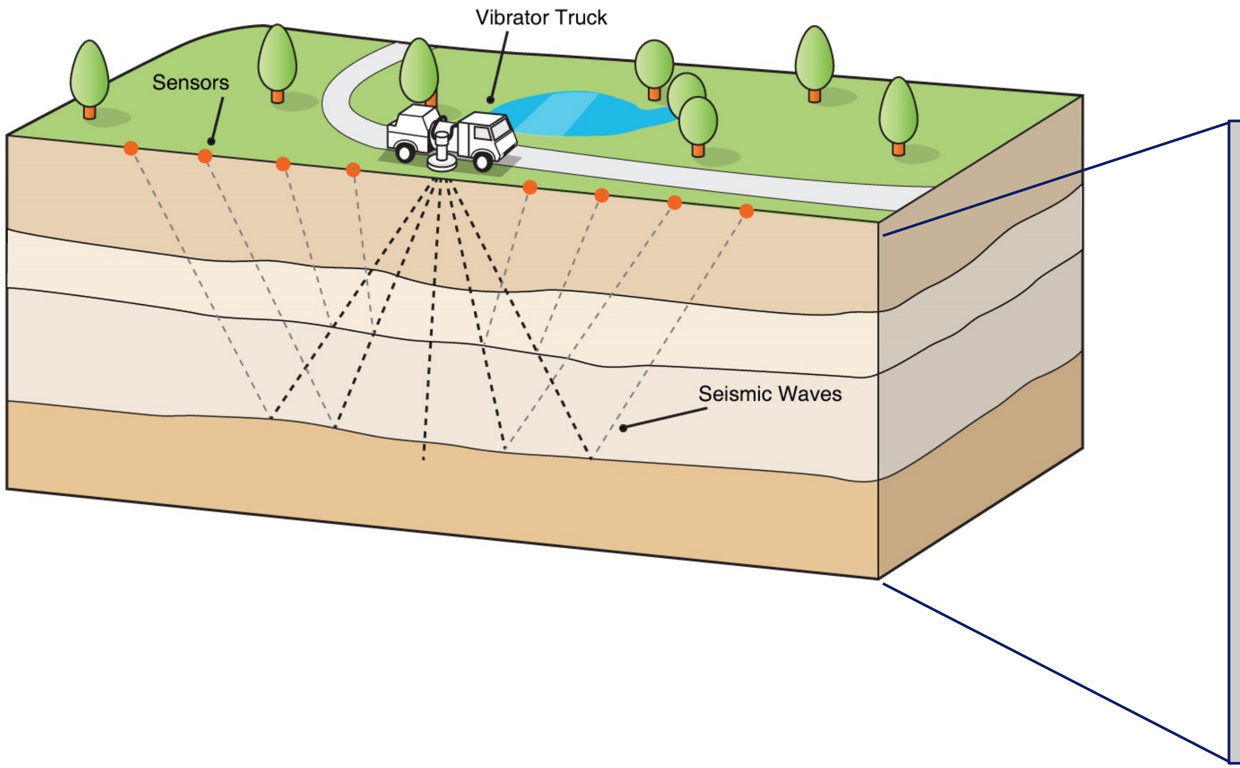


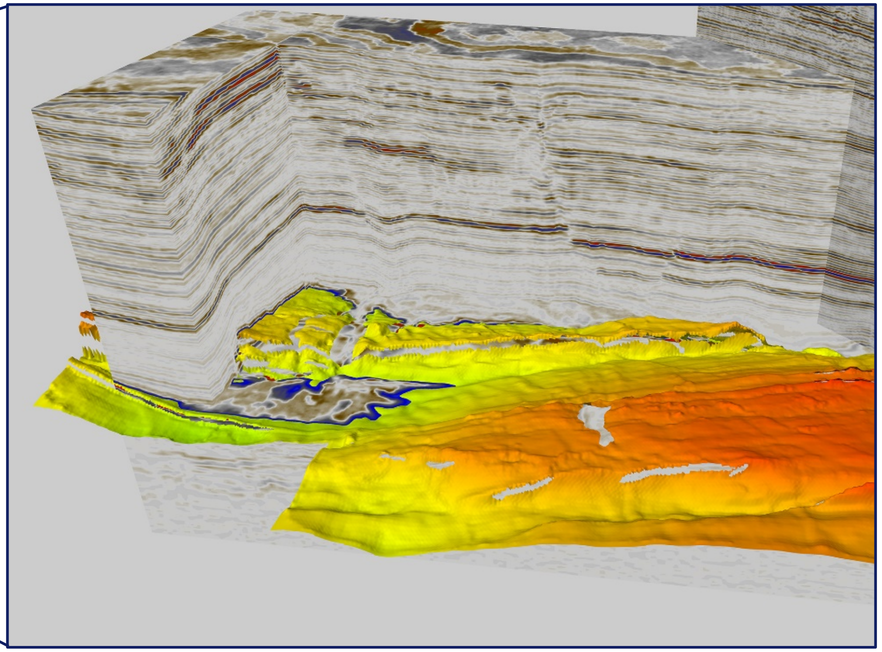
Measure seismic noise to improve gravitational wave detector

Slides courtesy Mark Beker Innoseis

Spin-off Example 1: From ripples in space-time to innovation in seismic imaging

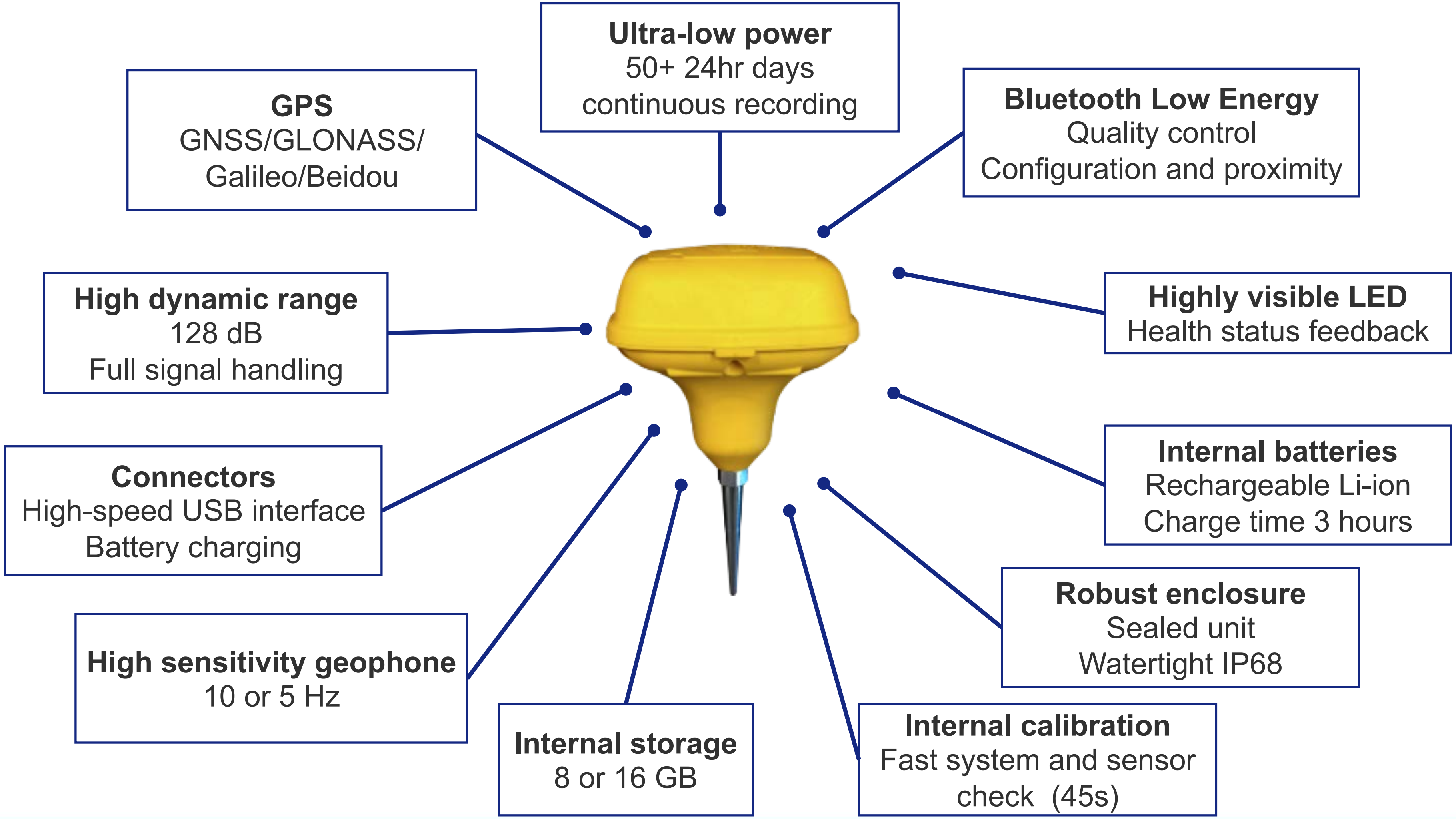
Natural gas and geothermal energy production can be safer, more responsible and done more cost effectively when high resolution images of the subsurface can be made





Slides courtesy Mark Beker Innoseis

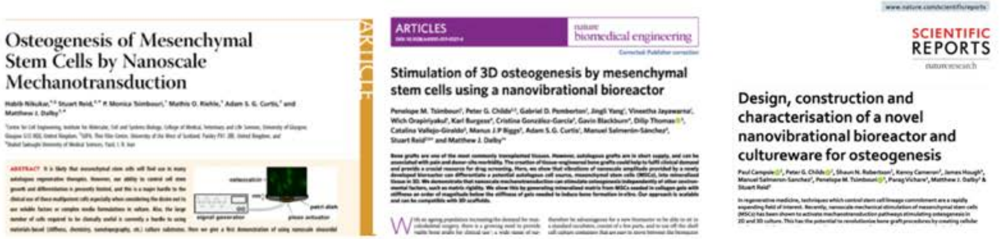
Spin-off Example 1: Lowest power and lightest weight seismic recording node on the market



Slides courtesy Mark Beker Innoseis

Spin-off Example 2: Nano-kicking, i.e. Stem cell differentiation

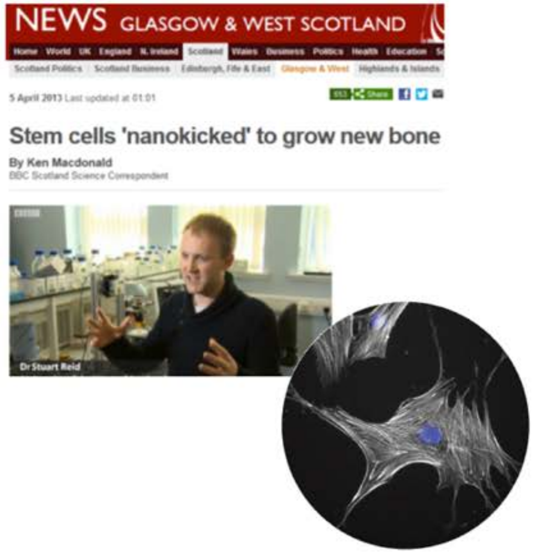
Precision measurement technologies (interferometry, FEA,…) for nanovibrational stimulation to control stem cell behavior



2D (ASC Nano 2013) 3D (Nature BME 2017) GMP Bioreactor (Nature Sci R 2019)

Implantable bone graft trials funded by landmine charity, Sir Bobby Charlton Foundation (£2.9M), and H2020 (€5.3M started June 2020).

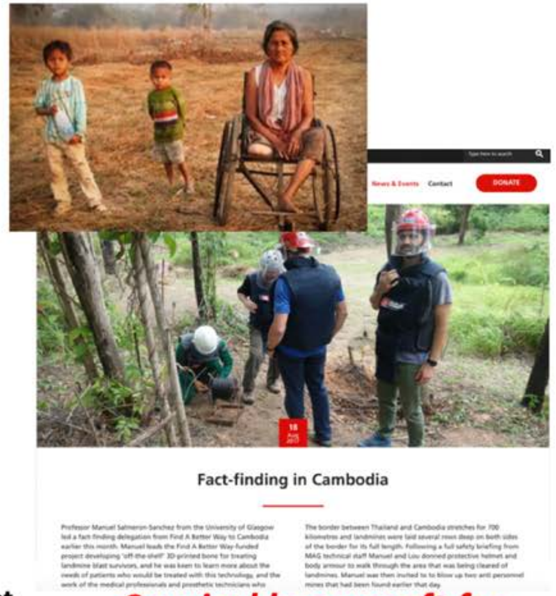
Nanovibrational ***treatment for osteoporosis*** trialled by NHS 2019/20.



Bone is the second most transplanted tissue after blood

NANOKICK TECHNOLOGIES

Alternative treatment for disuse osteoporosis



Surgical bone graft for landmine survivors

Slides courtesy Stuart Reid, Strathclyde University

Thank you very much for your attention!

Any questions ???