Earth Science Europe

A Forward Look to a Roadmap for Solid Earth Science in Europe for 2013-33 (and beyond)
Consultation document: January 2013

People like to dream: about the origin of the Earth, the universe and life itself
People need to be safe: from natural hazards especially catastrophic events
People want to be comfortable: to have a secure supply of energy, water and raw materials

Earth science research helps underpin all of this.

Our community MISSION:
To provide society with data, knowledge, new discoveries and inspiration to better understand the history and internal dynamics of our planet, and to better manage/ live more wisely on our planet.

Our Aims

- To enhance the status of Solid Earth science by establishing a coherent roadmap defining the science Europe needs
- To ensure fundamental, curiosity-driven Earth science research remains a key part of basic science programs, in parallel with society-driven research.
- To translate breakthroughs in basic research into practical applications to provide the solutions society seeks.
- To provide a research framework to manage resources and mitigate natural hazards and global change.

Where are we now?
A preliminary meeting was held (17-18 October 2012, Paris) where invited participants representing many geoscience initiatives focused on three key Questions:

1. *What are the principal **research questions** in Earth Sciences?*
2. *What **Research Infrastructure** is needed and how best to use / link what we have?*
3. *What are key areas for **Joint Programmes** and their general characteristics?*

We also discussed how to best *translate earth science into impact – both economic and societal.*

This document contains a distillation of ideas discussed at the preliminary meeting. We now invite ALL stakeholders to comment and provide further input. The document contains only the bare bones to be fleshed. We need you, the stakeholder community, to provide the details. All views are valid: the final Roadmap document is aimed at providing a description of the science needed for the future, and to act as a reference for a wide range of stakeholders: academia, Geological Survey organisations, policy makers and wider society alike[1].

[1] Main stakeholder groups:

- Research base (Academia)
- Geological Survey Organisations
- Science-Policy Interfaces
- Governments
- Funders
- Development organisations
- Business and Industry
- Civil Society (NGOs etc.)
- Media

Why now? What are the key drivers?

1. *Several current European initiatives aim to coordinate and promote research and infrastructure development across the scientific community, and roadmaps exist or are in preparation in many segments of this broad community.* An attractive and credible Earth Sciences roadmap is critical to leverage funds to continue critical research. The imminent launch of Horizon 2020 (H2020) will include both fundamental and applied science but its focus is squarely on grand societal challenges, training programmes and infrastructure. *Although recognizing the need for basic research, Horizon2020 emphasizes societally-driven challenges. There remains a need to recognize and define the scientific challenges and compelling questions that drive new discoveries in fundamental science.*
2. *Many [science] sectors have recognised groups, boards or platforms to represent them on the EU and wider world stage. It was agreed that is not only time for the Earth Science community to compile a roadmap of its future science requirements, but also to seek similar voice/representation at European level.*
3. To be competitive on the world stage, Europe needs a coordinated, comprehensive Earth Science research strategy. Publication of national earth science infrastructure and science plans/roadmaps by Australia, USA and Chinese governments, etc. demonstrate their commitment to Earth Science research and must be matched by a similar effort in Europe. Globalization of research also provides opportunities for collaboration and partnerships with developed and developing (i.e. BRICS) countries.

Key Research Questions

The overarching challenge for the research community is to understand the ***Geosystem as a whole****, by exploring processes acting in the different components of the Earth System and processes interlinking deep earth with surface envelopes, including the atmosphere and hydrosphere.*
How can we develop a 4D model of the Earth**?**

Key research areas combine fundamental science and societal challenges were identified and have been summarized by our writing team.

Overarching Themes:
- *Climate Change*
- *Natural Hazards and Risks*
- *Resources (Water, Rare materials, Energy)*
- *Origins*
- *Earth Dynamics*

Major Challenges
Climate Change

1. ***How can we mitigate risk from natural hazards and make society more resilient to them?*** Establish the nature and scope of Earth and environmental change in response to a changing climate in order to provide the boundary conditions for engineers and policy makers working to mitigate impacts and hazards. The Earth system responds to changing climate in complex

ways far beyond changing weather. Extreme events such as floods depend on precipitation patterns in space and time and the surface and groundwater response to changes in long term patterns. Changes in vegetation and ecosystems affect runoff and evapotranspiration and thus regional hydrology, soil erosion and hill-slope stability. Coastal erosion rates and processes depend not only on rising sea level, wave direction and the influence of old defence systems, but also storm frequency and magnitude which are arguably changing. In a changing climate, extreme weather events, meaning both heavy rain and extended droughts, could become more common. Heavy rain can lead to natural hazards due to flooding and gravitational mass wasting. The effect of climate change on the frequency and magnitude of these events is currently not well understood. Research in the Earth Sciences can help to better understand processes leading to and driving these events, to develop operational forecasting tools, and to quantify impact on society. Thus, risks may be mitigated, and society can implement infrastructures and management processes to prepare for and to deal with such events.

2. ***How can we integrate the different proxies and sample types in order to model and understand climate sensitivity?*** The record of the earth system response and sensitivity to climate change is contained in the myriad of geo-archives represented by marine and terrestrial sediments, ice, chemical precipitants and other proxy records. Study of past events and Earth history is key to our understanding of the present and future response of the planet to climate change. A key role is played here by Quaternary palaeo-climatology especially, studying the most recent changes. A major challenge is the integration of information derived from different chemical, biological and physical proxies and sample types into a coherent picture.
3. ***How can we evaluate the impact and response of the Earth, ecosystems including the role of our civilization to past and future climate change through hydrologic processes and mass wasting?*** The Holocene contains the Earths most complete record of climate and environmental change, including ecological and anthropological responses. Study of the response of early civilization to external forcing such as climate change and internal forcing brought on by the rise of agriculture and pastoralism, for example, through soil degradation and water use, provide important lessons on the ecological and the human response to environmental stress. Society must respond to a changing spatial and temporal distribution of water caused by climate change. How agricultural methods, power production and recreative activities can be adapted to the new climate situation is major research challenge in the coming decades.

Natural Hazards and Risk

4. ***How can we establish better physical basis for earthquake, landslides and tsunamis and other natural hazards?*** Most deaths arising from natural hazards in recent decades were caused by disasters associated with Earth processes such as ground shaking during earthquakes or the emission of volcanic materials during eruptions - although many of these were caused by secondary hazards, such as terrestrial and submarine landslides and tsunamis, which may be the main killers. It is critical that we improve our understanding of the processes that drive hazardous processes, such as those associated with the brittle-ductile transition, and improve our capacity to probabilistically forecast hazards.
5. ***How can we best communicate the risks, implications and impacts to society?*** Understanding the contribution of multiple hazards to risk, in conjunction with measures of exposure and vulnerability is a critical area for science and social science research. Improved modelling and communication of risk to facilitate societal mitigation of impacts is a major challenge.

Resources

How can we establish better means to assess extent, genesis, conservation, and means to safely exploit natural resources including energy, renewable and non-renewable, water, and metals, and deal with waste? The supply and consumption of natural resources offers diverse challenges, both within Europe and on the global stage. Sources of energy will evolve, with renewable resources playing an increasing role. Use of alternative sources such as shale gas will require the development of reliable and safe recovery methods and, perhaps more importantly, education of both decision-makers and the general public by supplying them with reliable unbiased information. Access to abundant clean water will become increasingly difficult in much of southern Europe and in major cities in coming decades. Protection of ground- and surface waters from over-exploitation and pollution will be a major scientific and technological challenge. To lessen Europe's current near-total dependence of imported metals and to assure security of supply of the metals needed for modern technology and industry may require a resurgence of mining within many European countries combined with reactivation of research in economic geology and the training of ore geologists, and a vigorous campaign to obtain social licence for a domestic minerals industry. The key challenge areas include: Sub-surface storage of resources & wastes (e.g. water, CCS, radioactive waste); In-situ energy mining (e.g. geothermal, coal and shale gasification); Minerals for emerging technologies & infrastructures (e.g. rare earths, biominerals, aggregates); Enhanced recovery of resources (e.g. oil/gas recovery, mineral recycling, unconventional hydrocarbons) and Scenarios & risk modelling.

Origins

7. ***Early Earth – what is the origin? How did the core, mantle and crust, the atmosphere and oceans evolve and life emerge?*** The origin of life – why are we here? – is arguably the most compelling question of the earth sciences. The Earth Sciences have made significant progress in this domain in the last decade, but key details remain elusive. What is the balance between the different accretionary materials that formed the Earth, their mass and sequence of their accretion? Which processes operated in the deep primitive Earth and what was their role in building a habitable planet: one capable of supporting life? Why is the Earth unique; so different from its cousin planet Venus where there is no plate tectonics, no water, no magnetic field, no life? The field is multidisciplinary, ranging from field geology through geochemistry and biochemistry, planetary science, to experimental investigation and numerical modelling of core formation, mantle crystallisation, and early crust formation. Where do we stand on paradigms such as the Late Veneer, and its impact on the Earth system? Solving these questions provides the starting point and boundary conditions for models that attempt to quantify and identify the processes that show how the deep Earth, its oceans and atmosphere have co-evolved with life since the very birth of time. Through research on conditions at the surface of the early earth, we can define the habitat in which life emerged and evolved during the early history of our planet. Europe earth scientists are currently at the forefront of this research and have access to much of the equipment needed to advance our knowledge in this field.

Earth Dynamics

8. ***How has the deep Earth controlled the evolution of Earth as an active and habitable planet?*** At an early point in its history the Earth system stabilised to a point where its oceans and atmosphere were established, its core formed and its early molten mantle solidified, and proto-continents were distinct from a basaltic crust. The dynamical properties of deep-Earth materials (rheology, transport properties) have since played the most fundamental

role in determining how Earth convects and loses its heat. The style and vigour of convection controls the growth of the continents and transport of volatiles out of the mantle to the oceans and atmosphere. It can also give rise to deep isolated geochemical reservoirs, or destroy them. To some extent, the large reservoirs on Earth today are a fingerprint of processes that occurred over 4.5 billion years ago, and these processes are still poorly understood. Loss or recycling of material into the mantle, especially water, can have a dramatic effect on mantle rheology and its convective mode. Understanding this feedback and evolution of the interior dynamics of Earth nevertheless remains enigmatic. Because of the role of this process in quantifying the mass flux of elements to and from the Earths surface, and therefore Earth's ability to sustain a habitable surface, this field remains one of the grand challenges in the Earth sciences today. With advances in experimental petrology and mineral physics, geophysics, laboratory experiments, numerical simulations and geochemistry, we have the capability today with a coordinated and sustained effort to make significant progress in this field.

9. ***What are the connections between deep Earth dynamics, surface processes, hydrology and climate?*** Multi-scale understanding of plate tectonics and plate motion timescales, linking many disciplines and infrastructure, studying linkage of deep earth (mantle and core processes) and shallow (crustal) process. Modelling the past earth system and how it evolved is essential to understanding climate and elemental cycles.

Research Infrastructure

In order to deliver the research, access to and investment in new and existing infrastructures will be required. Whilst much of the necessary infrastructure already exists at the national level, we need increased coordination and additional European component/dimension and development of the necessary infrastructure to share outputs (basic data, derived data, models etc.) to drive down individual costs. Greater participation of the private sector in fundamental and applied research should encouraged R&D conducted within the business sector was 1.23 % of GDP in the EU, compared with 2.70 % in Japan and 2.02 % in the United States. Industry-funded research is minimal in the earth sciences, lagging far behind sectors like the biosciences, nanotechnology and pharmacy. Industry-government funded earth-science research facilities and programs are common in USA and Canada, present in the UK, but virtually absent in the rest of Europe.

Specific Infrastructure needs –*are these comprehensive?*

- Multi-parameter observatories and research centres (linking geophysics, geochemistry, hydrology, meteorology, environmental parameters etc.) at supersites providing permanent integrated monitoring of key, integrating land-marine-remote components, including continental shelves, the Artic, faults and natural hazards.
- Multi-parameter equipment pools to enable increased resolution on specific areas/problems and bridge with exploration geophysics .
- Mobile field equipment for large scale European field experiments
- Dedicated multi-parameter-satellite missions for the earth science sector
- Drilling equipment: Seabed, land, fault zones, Ice
- Network of borehole observatories (Basin studies, Modeling)
- Marine cable networks (high synergy effects to other communities)

- Linking of existing ice and sediment core data, linkage of marine and continental infrastructure e.g. a data portal for climate proxies in Europe
- Analytical facilities: Geochemical, geomechanical, geochronological laboratories – many already exist and there is a need to identify best labs; jointly decide on access; joint training, European standard laboratory facilities including sample preparation
- IT (including HPC)
- High-grade curation facilities for safe/biosafe environments
- Increased collaboration and co-funding of research by public agencies and industry
- Data storage and management systems to allow information sharing and service provision to the different user communities: academic, industry, government and public.

These are all required at *European level*, with current national facilities linked up or providing open access to all.

Joint Programming

The need for long-term multi-disciplinary international programmes is clearly recognised. Possible themes for large-scale programs of value for Earth Sciences in Europe, many with obvious demonstrable component of societal relevance, which could be developed under Horizon2020 as **coordinated research (CR) or infrastructure programmes (RI)** and/or Joint Programming Initiatives (JPIs[2]) are listed below:

- Georesources (including fossil and renewal energy sources and minerals) (possible JPI[3]; industry input essential) (CR)
- Geosciences and society – impacts and communication (CR)
- Geosecurity (including megacities) (CR)
- Extremes and threats (natural and man-induced) (CR)
- Climate Sensitivity, Impacts and Adaptation (CR)
- Deep Earth and surface interactions (including climate) (CR)
- Origins (life, Old Earth, Solar System and other planets, sudden onsets, volatiles) (CR)
- Fluid-flows (CR)
- Geomicrobiology (CR)
- How does Plate Tectonics work?? A new plate tectonic paradigm (RP)
- Multi-parameter observatories (RI)
- Satellite arrays – deep observations and improved temporal and spatial resolution (RI)
- Drilling Europe (RI)
- Data sharing (RI)
- Training Facilities - Recognition of training needs for the next generation of earth scientist, and specialist teaching by specialists in their fields to serve academic, industry and society.

Impact

[2] http://ec.europa.eu/research/era/areas/programming/joint_programming_en.htm

[3] The assembled parties present in Paris 17-18 October 2012 agreed that there was a clear opportunity for a Joint Programming Initiative based around Geo-resources.

How can we as Geoscientists convince decision makers and the public at large of the intrinsic interest of our science and its value to society?
There is an obvious need to improve information flow at Interface with stakeholders, and especially to the wider public.

Whilst the key objectives for the Earth Science Europe is to provide a coherent roadmap for Earth Science in Europe over the next 20 years, then it is equally important to find credible face(s) to publicize the roadmap.

Key themes for the next 20 years

- Integration of research and monitoring efforts
- Harmonisation of methodologies
- Data and sample sharing – and storage/archiving
- Sharing/establish shared facilities

Three pillars

- Science
- Infrastructure
- Society (Impact and communication/KT)

Final Deliverables/Aims

Roadmap documents

1. A general high-level document, a relatively short glossy document summarising the science, scientific needs and relevance to European citizens for the next 10-20 years, such as The Royal Astronomical Society's : A New View of the Universe: Big Science for the Big Society.
2. A pure science document for scientific community's use, rather than the wider stakeholder use e.g. the US National Science Foundation GeoVision etc.

Goals

- To position European earth science on the world stage
- To raise the standing of Earth Science on National Agendas
- To influence forthcoming H2020 calls and work programmes (leverage funding)
- To form the basis of an independent European platform to represent the [Solid] Earth Science community – a Board to represent the Geosciences, to promote collaboration and provide a voice for the community at European level. **Annex 1**

Earth Science Europe

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Have your say!

What have we missed?
How can this be achieved?

Comments on this document and the initiative and its aims should be sent to the initiative coordinator:

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Closing date for comment: 31 May 2013

ANNEX 1

A Solid Earth Science Board?

Overarching Aim:

To provide a pan-European platform for its member organisations to develop common priorities, to advance solid earth science research and to bridge the gap between science and policy, in order to meet future earth science challenges and opportunities. It should be a platform for European engagement in international science programmes and provides strategic science policy advice to the European Commission and international bodies.

As an **independent non-governmental advisory body**, the Board should develops insight and foresight, recognising opportunities and trends, presenting compelling and persuasive arguments that shape the future of earth science research in Europe

A Board should facilitate enhanced cooperation between national organisations involved in solid earth science (both research institutes and research funding agencies), European stakeholder networks and wider stakeholder communities, towards the development of common positions on the research priorities and strategies for solid earth science in Europe.

In its strategic role, such a Board would serve its Member Organisations by providing a forum within which earth science research policy advice to national agencies and governments and to the European institutions and agencies is developed, with the objective of promoting the establishment of the European *Marine* Research Area.

A European Board would operate via four principle approaches which underpin the Board's main objective of bridging the gap between science and policy

1. ***Forum*** – bringing together research stakeholders to share knowledge, to identify common priorities and approaches, to develop common positions and perspectives, and to collaborate;
2. ***Synergy*** – fostering European added value to national programmes, facilitating access and shared use of national research facilities, and promoting synergy among international programmes and organisations;
3. ***Strategy*** – identifying disciplinary and inter-disciplinary scientific issues of strategic importance for Europe, initiating analysis and studies, and providing high-level recommendations for European and national programme managers, research funders and policy makers as well as the scientific community;
4. ***Voice*** – expressing a collective vision of marine research priorities towards a European strategy for research, in order to meet future science and societal challenges and opportunities.

Current examples

Marine Board http://www.marineboard.eu/

Polar Board http://www.esf.org/research-areas/polar-sciences.html