Technology & Energy: Scoping the Future requirements to support Antarctic science in the near- to mid-term future

Topical White Paper to the Antarctic Roadmap Challenges (ARC) Project
on behalf of the **COMNAP's Technology & Energy Expert Group**

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Summary

Antarctic science would not be possible without technology and energy that are required in support of a wide range of activity across diverse research disciplines. Some technologies evolve specifically for an Antarctic application or purpose, while others evolve outside of the Antarctic arena but are brought across and are capable of functioning in Antarctic conditions. The COMNAP Antarctic Roadmap Challenges (ARC) surveys provided a template identifying the most important technological issues related to future Antarctic science. These are briefly summarised below along with any gaps in technology that require consideration and development. The surveys did not, however, explore energy requirements. All technology deployed in Antarctica requires robust and reliable energy sources. All equipment transported to/from Antarctica is transported by way of air or marine vessels, both of which currently require fossil fuels for propulsion. Understanding battery innovations and sustainable energy solutions and when, where and how such can be deployed will be a significant challenge for national Antarctic programs in supporting future science.

Direct technological challenges

The ARC Survey identified a number of technologies of critical importance to advancing future Antarctic science. These included what we refer to as "On-site technologies", that is, technologies that must be deployed and used in Antarctica and "Off-site technologies" which are those technologies which are required for use in home institutions once data from Antarctica has been collected or made available.

Critical on-site technologies include:

- Clean sampling technologies
- Sample handling and analysis techniques at in situ conditions
- Continuous robust measuring sensors (incl. automatic weather stations with expanded and robust sensor arrays, remote solid Earth sensors arrays, as well as the ice, sediment and rock down boreholes loggers and sensors); for remote locations also with the wireless long-distance data transfer capabilities
- On-site advanced laboratories
- Ice sheet and shelf observatories
- Network of stations continuously conducting global-challenge monitoring (i.e. atmospheric, air pollution, wave energy, etc.) in both polar regions
- Below ice sheet observing systems and the associated power and sensors requirements

- Sub-glacial sampling technology (incl. ice sheet/ice shelf drilling/core recovery technologies)
- Oceanic sea bed drilling/core recovery technologies
- Remotely operated sensors carriers (underwater ROWs and UAUVs, as well as aerial UAVs) with expanded sensor payloads
- Deep water and under ice moorings and (towed) floats with tethered and/or wireless data transfer capabilities.

Off-site technologies include:

- Establishment of and long-term support for open-access research databases
- Advanced data analysis techniques
- Advanced "-omics" techniques
- Improved models (climatological, glaciological, geological, ecosystem as well as integrated Earth system models)
- Calibration/validation of available satellite sensors
- Expanded telescope and astrophysics sensor arrays

Developing energy and technology requirements in the context of the Antarctic area

Given the special status of Antarctica as a "natural reserve, devoted to peace and science" the development and deployment of technologies must be done so in the context of other challenges and obligations. These we refer to here as "non-direct research-related" issues. They fall under the broad categories of environmental management and protection obligations, logistics challenges, and safety, maintenance and comfort considerations.

Non-direct research-related technological challenges

Environmental management and protection obligations

There have been considerable advances in sustainable technologies over the past 20 years and deployment of such technologies at Antarctic stations and in field locations has progressively been completed across most of the national Antarctic program's operations. These are particularly useful in summer, and at summer-only facilities, but as yet are not reliable enough to use at winter-over stations or to run marine vessels such as ice breakers, which, per capita, utilise the most fuel of any Antarctic technology. Therefore, any request for increased marine science carries with it an increase in fuel requirements, for example, and any increase in winter-over facilities would mean the same.

The community recognises that there is a need for:

- Development of renewable energy source technologies suitable for Polar regions and a significant rise in their progressive utilization through the Antarctic stations when appropriate
- Development and broad use of the environment friendly technologies to avoid the contamination of the Antarctic by the non-native species (e.g. UV-C radiation to treat

the fresh vegetables at the Antarctic stations) especially if scientists are requesting the opening of new areas of Antarctica in order to carry out their science

- Development and broad use of low energy waste (water) treatment technologies with no harmful impact to Polar ecosystems (incl. use of low temperature biological washing technologies)
- Development of environment friendly and Polar conditions resistant construction materials
- Development and broad use of environment friendly and resistant exterior protection technologies (e.g. anti-peel-off paints or coats to protect the installations against the harsh climate conditions)

Development of many of the above requirements may take place first for applications not specifically of an Antarctic or polar purpose, but may be modified and adapted to fit the Antarctic situation. Thus, the Antarctic community needs to remain well-aware of such advances and their possible application to an Antarctic purpose.

Logistics Challenges

Year-round access to the Antarctic was the top response across all but one of the seven Horizon Scan science clusters. This request comes with obvious challenges in most of the regions of the Antarctic. All access to Antarctica (i.e. to coastal regions, to high-plateaus, to the Antarctic interior, at stations or at deep field camps), at any time of the year is generally very complicated, technically difficult and expensive, and any increase in current level of activity implies the requirement of increased icebreakers, other ships, aircraft, and winter-over station availability. It would also require an increase in personnel who have the expertise and personal skills necessary to support the range of Antarctic winter science.

While all access is challenging, there are particular deployment and maintenance issues related to:

- Remote placement of instrument arrays
- Manned and/or unmanned airborne and/or (deep) water sensors carrying crafts and/or sampling devices
- Placement of networks of ocean buoys.

Safety, maintenance and comfort issues

The geographic isolation of the Antarctic area means that inter- and intra-continental communications infrastructure is required. Our ability to transfer data into/out of polar regions, especially in winter is restricted by the low availability of communications satellites and other infrastructure at high latitudes. This highlights not only a technical issue, but a social issue, since the high latitude areas are relatively devoid of people and therefore are perceived by technology companies as not worth their commercial efforts. Other social issues are also involved.

Clearly in order to deliver future Antarctic science, there is a need for the:

- Establishment of broadly available communication ways suitable for the high latitude locations (incl. e.g. large data transfer capabilities), when the shared capacities enable lower prices and therefore better availability

- Establishment of and long-term support for National Antarctic Programmes' access database of personnel suitable for the Antarctic stations
- Establishment (respectively further improvement where already exist) and constant mandatory updating of the international rescue-purposes networks and databases - both for the marine-operated research and for the land-based expeditions

Recommendations

International collaboration has always been the key to success in the Antarctic. This remains true in the context of efforts required to achieve described and desirable technological progress. The issue is one of funding and of putting in place a strategy across national Antarctic programs to begin to address one or two key technology, access, logistics or infrastructure challenges. This will also likely have to be done in collaboration with non-Antarctic communities, such as those developing technologies for space or deep ocean research.

All National Antarctic Programmes should inspire their engineers, technicians, researchers and other professionals to be involved and focused on these challenges. Forums for exchange of ideas are already in place, but may be underutilized at this time. The COMNAP's Expert Group on Technology & Energy is the perfect forum to exchange the experiences on the practical aspects of the desired technologies' development and utilization, or to create a database of technologies research centres already working on marked issues to enable and support collaboration as well as to prevent unnecessary overlaps.

This group should also reach out to traditional non-Antarctic organisations, in particular in reference to energy requirements and innovations, but also in regards to aircraft, ships, and to unmanned instrumentation systems. Most companies will assist to address a challenge if a significant need is identified.