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Architecture in an Extreme Environment (A case of Halley VI Research Station)

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Abstract
This work evaluated architecture in an extreme environment. The main study focused on Halley VI research station in Antarctica. To achieve this, the qualitative - expository research design was adopted for this study. The review of Antarctica as an extreme environment was discussed in relation to climate, temperature, economic and living condition of residents. Also, the early Halley research stations, data collected for this paper were majorly from secondary sources. The data collected were solely qualitative in nature and the content analysis method was used to glean out facts from articles, textbooks, newspapers, relevant websites and electronic journals linked to Research Gate, Scopus, Academia.edu and other significant internet sources. Inferences were drawn on the basis of the researcher's views in relation to the position of scholars from previous literature. Based on the review, it was uncovered that Halley VI was built over four summers. It was completed in 28 February 2012 but officially opened 2013. The structure is modular with a building cost of approximately £26 million. Halley VI is a string of eight modules which, like Halley V are jacked up on hydraulic legs to keep it above the accumulation of snow. Unlike Halley V, Halley VI has retractable giant skis on the bottom of these legs, which allows the building to be relocated periodically.

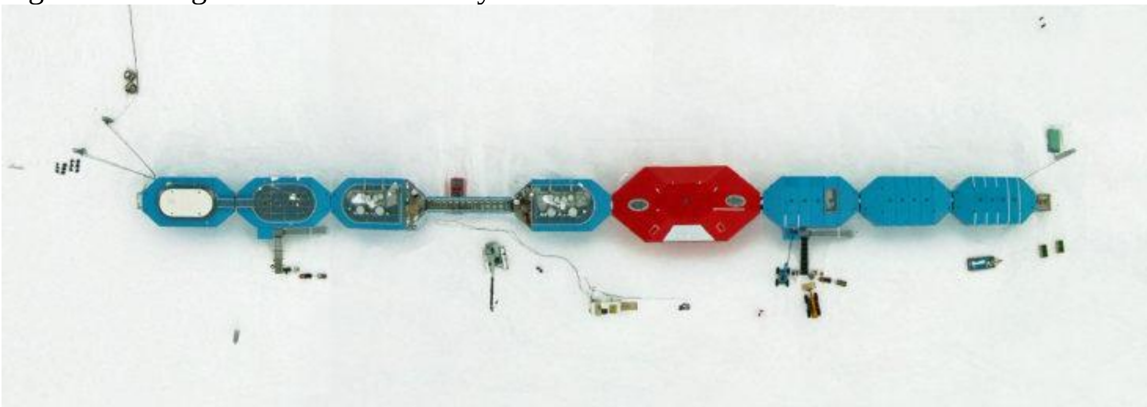
Introduction

Extreme environment is an environment where conditions are challenging to survive, whether climatic, economic, or social. In these spaces, man or other life forms would die if they did not have some protection (Smith, 2005). An extreme environment can be an extensive desert, a glacier, a very high mountain, a trench in the ocean, a war, a famine, or a humanitarian crisis caused by a natural disaster (Muller, 2000). As a result of industrialization, these extreme environments have been intensifying and multiplying in recent years.

One of the major aims of the Halley VI project was to minimize the environmental footprint of the station. The facility uses the latest energy-saving technology, including bioreactors for sewage treatment and two-stage incinerators for the clean burning of certain types of waste. Translucent nanoaerogel panels, the most thermally efficient material known, were incorporated and substantially reduce energy loss in the extreme, harsh climate (BAS - Science, n.d.).

The successful delivery of Halley VI was a fantastic example of design, innovation, construction and procurement at its best, requiring an intimate collaborative process between client, design team, main contractor and supply chain. The design and construction included unique technology transfer from other industries, and a range of totally original inventions (BAS - Science, n.d.).

Fig. 1: Showing Aerial view of Halley VI Research Station on the Brunt ice shelf Antarctica.



Source: *Halley VI Research Station; British Antarctic Survey Natural Environment Research Council.*

The Halley VI Research Station is an internationally important platform for global earth, atmospheric and space weather observation in a climate sensitive zone (Antarctica). (BAS - Science, n.d.).

Data gathered by scientists at Halley as part of European collaborative projects such as SPACESTORM. By generating more accurate space weather forecasts, this science has helped reduce the impact of space weather events on satellites.

In 2013, Halley was made part of the network of 30 stations across the globe that form the World Meteorological Organization's Global Atmosphere Watch (GAW) programme, becoming the 29th in the world and 3rd in Antarctica. (BAS - Science, n.d.). Together, these stations provide reliable information on the chemical composition of the atmosphere and how it is changing.

Measurements of ozone, as well as meteorology, have been made at Halley since it was established in 1956. This long-term data enabled British scientists to discover the hole in the ozone layer in 1985. (BAS - Science, n.d.). At Halley typical winter temperatures are below -20°C with extreme lows of around -55°C. There is 24 hour darkness for 105 days per year. (BAS - About, n.d.).

Research Problem

Climate change is becoming increasingly evident, and areas of the planet that were once habitable are being transformed into hostile places. Consequently, we see more often population displacements, poverty, wars, pandemics, and, of course, new uninhabitable places (Roaf, 2005). Faced with this challenge, the development of architecture in extreme environments is increasingly important (Abiboo Studio, 2021).

The knowledge it produces is key to imagining and proposing structures and systems that guarantee humanity's survival in any possible scenario. For example, as a consequence of climate change, architecture can respond to the episodes of extreme heat and cold with specific thermal insulation solutions. Or create temporary shelters for the most vulnerable populations (Rassia, 2014).

Scientific research at Halley date back to 1956 and are recognized globally as critical for understanding how and when the ozone hole will recover and how our climate will respond to future change, and how extreme space weather events may affect the satellite industry. Halley is ideally located to measure atmospheric phenomena such as space storms. (Davis, 2017). The aurora Australis is the visible sign of storms in space.

Literature Review

Antarctica is Earth's southernmost continent. It is a cold, remote area containing the geographic South Pole and is situated in the Antarctic region of the Southern Hemisphere, almost entirely south of the Antarctic Circle, and is surrounded by the Southern Ocean. At 14,200,000 square kilometres (5,500,000 square miles), it is the fifth-largest continent and nearly twice the size of Australia. It is by far the least populated continent, with around 5,000 people in the summer and around 1,000 in the winter. About 98% of Antarctica is covered by ice that averages 1.9 km (1.2 mi; 6,200 ft) in thickness (The Cove, 2022).

Antarctica, on average, is the coldest, driest, and windiest continent, and has the highest average elevation of all the continents. Most of Antarctica is a polar desert, with annual precipitation of 200 mm (8 in) along the coast and far less inland; yet 80% of the world freshwater reserves are stored there, enough to raise global sea levels by about 60 metres (200 ft) if all of it were to melt. The temperature in Antarctica has dropped to -89.2 °C (-128.6 °F) (or even -94.7 °C or -138.5 °F, as measured from space), though the average for the third quarter (the coldest part of the year) is -63 °C (-81 °F). Organisms native to Antarctica include many types of algae, bacteria, fungi, plants, protista, and certain animals, such as mites, nematodes, penguins, seals and tardigrades. Vegetation, where it occurs, is tundra (Kong, 2012).

Several governments maintain permanent, staffed research stations on the continent. The number of people conducting and supporting scientific research and other work on the continent and its nearby islands varies from about 1,000 in winter to about 5,000 in the summer. Many of the stations are staffed year-round, the winter-over personnel typically arriving from their home countries for a one-year assignment (Davies, 2022). An Orthodox church, Holy Trinity Church, built in 2002 and opened in 2004 at the Russian Bellingshausen Station is manned year-round by one or two priests, who are similarly rotated every year. (Bartlett & Smith, 2023).

Halley Research Station is a research facility in Antarctica on the 130-metre thick floating Brunt Ice Shelf, operated by the British Antarctic Survey (BAS). The base was established in 1956 to study the Earth's atmosphere. Measurements from Halley led to the discovery of the ozone hole in 1985. The current base is the sixth in a line of structures and includes design elements intended to overcome the challenge of building on a floating ice shelf without being buried and crushed by snow. As of 2020, the base has been left unmanned through winter since 2017, due to concerns over the propagation of an ice crack and how this might cut off the evacuation route in an emergency. The Halley Bay Important Bird Area with its emperor penguin colony lies in the general vicinity of the base.

The first relocatable research station in the world with raised legs is the British Antarctic Survey Halley VI, and this came with connected modules that were moved independently as snow accumulation was displaced.

The British Antarctic Survey's Halley VI was the world's first relocatable research station, with raised legs which counter the accumulation of snow, and connected modules that can be moved around independently. **(Source:** http://architecturecompetitions.com/architecture-in-extreme-environments Built on a floating ice shelf in the Weddell Sea, the Halley VI Research Station enables scientists to study pressing global problems within state of the art laboratories, such as climate change, rising sea levels, and the ozone hole (which was first discovered at Halley in 1985). Halley VI is segmented into eight modules, each sitting atop ski-fitted, hydraulic legs which allow each module to be towed independently to a new location.

There have been five previous bases at Halley. Various construction methods have been tried, from unprotected wooden huts to buildings within steel tunnels. The first four all became buried by snow accumulation and crushed until they were uninhabitable. (**Source:** http://en.wikipedia.org/wiki/Halley_Research_Station The more recent structures have been designed to remain on the snow surface.

Halley I: was built in 1956, main structure was a main living hut by 1961 and an office block on surface by 1964. It was abandoned in 1968, the structure had evolved to a Timber hut.

Halley II: was built in 1967 and abandoned in1973. The Structure consisted of a series of wooden huts. The roofs were reinforced with steel supports to help support the weight of the snow but the station still had to be abandoned in 1973, after just six years.

Halley III: was built in 1973 and abandoned in 1983. In 10 years the base was buried 12–15 metres below the surface and access and ventilation problems led to its abandonment. Years later it emerged from the ice cliff at the sea. (**Source:** http://en.wikipedia.org/wiki/Halley_Research_Station)The structure, built inside Armco steel tubing designed to take the snow loadings building up over it

Halley IV: was built in 1983 and abandoned in 1994. The structure was a Two-storey buildings constructed inside four interconnected plywood tubes with access shafts to the surface. The tubes were 9 metres in diameter and consisted of insulated reinforced panels designed to withstand the pressures of being buried in snow and ice. Designed to cope with being buried in snow.

Halley V: was built and completed 1990, operational till 1989 and demolished late 2012

Once its successor, Halley VI, was operational, Halley V was demolished. The structure consist of the main buildings which was built on steel platforms that were raised annually to keep them above the snow surface. Stilts were fixed on the flowing ice shelf so it eventually became too close to the calving edge. The platform was of Lawes platform.

Drewry Summer Accommodation: this consist of a two-storey building and was on skis and could be dragged to a new higher location each year. The Drewry block was later moved to join the Halley VI base Simpson Building (Ice and Climate Building) (ICB): On stilts and was raised each year to counteract the buildup of snow. It housed the Dobson spectrophotometer used to discover the ozone hole. Piggott platform (Space Science Building) was used for upper atmosphere research.

Research Methods

The design of the study or research design is the spec-analysis of the data and procedure needed to attain a research fit. It is the arrangement of conditions and analysis of data in a manner that is aimed at combining relevance to achieve a research purpose (Saunders, Lewis & Thornhill, 2003). Consequently, research designs are typically classified according to the nature of the research objectives or type of research. For this paper, the qualitative - expository research design was adopted for this study. Imahe and Uddin (2000) noted that the qualitative-expository research design is aimed at widening or awakening prospective readers to the values of a discovery by reviewing or discussing its inherent benefits. Hence, the expository research design was used in this review. This was chosen because the research sought to awaken prospective readers or information users.

Data collected for this paper were majorly from secondary sources. The secondary data collected for the review of previous literature were from textbooks, electronic journals, newspapers, and other internet sources. Hence, the researcher was simply trying to make generalizations based on content review from previous literature on pension fund scheme administration. Hence, secondary data from textbooks, electronic journals, newspapers and other internet sources were solely used to draw inferences from reviews and make generalizations.

The technique of analysis was basically the descriptive-expository approach. Since the data collected are solely qualitative in nature, the content analysis method was used to glean out facts from articles, textbooks, newspapers, relevant websites and electronic journals linked to Research Gate, Scopus, Academia.edu and other significant internet sources. Inferences were drawn on the basis of the researcher's views in relation to the position of scholars from previous literature.

Findings and Discussion

Halley VI was built over four summers. It was completed in 28 February 2012 but officially opened 2013. The iconic research facility of Halley VI was designed by AECOM and Hugh Broughton Architects for the British Antarctic Survey (BAS) and was built in Antarctica by Galliford. The structure is Modular with a building cost of approximately £26 million. Halley VI is a string of eight modules which, like Halley V, are jacked up on hydraulic legs to keep it above the accumulation of snow. Unlike Halley V, there are retractable giant skis on the bottom of these legs, which allow the building to be relocated periodically (Nash, 2010). The innovative design of the new research station is pioneering in its use of engineering and technology. Being the first built modular facility which was relocated in Antarctica. It has designed with it science and life support modules, with six blue accommodation, one large social red module to provide scientist safe place to work and live.

The Drewry summer accommodation building and the garage from Halley V were dragged to the Halley VI location and continue to be used. The Workshop and Storage Platform (WASP) provides storage for field equipment and a workshop for technical services. There are six external science cabooses which house scientific equipment for each experiment spread across the site and the Clean Air Sector Laboratory (CASLab) 1 km from the station.

The 80-tonne module was successfully elevated using its hydraulic legs, supported on its giant skis and freed from the snow build-up. To cope with the movement of ice shelf towards the sea it is likely that the modules will be relocated inland every five years. The facility is expected to have a longer life than any previous British station on the Brunt Ice Shelf.

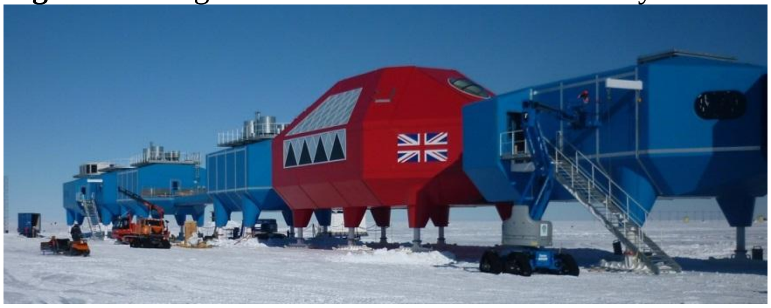
The construction team left Antarctica in March as winter was approaching. All seven modules were fully clad weather-tight and ready to endure the harsh winter months. The next phase of the project, planned for the 2010-11 season involved fitting out the modules and commissioning the technology.

An architectural design competition was launched by RIBA Competitions and the British Antarctic Survey in June 2004 to provide a new design for Halley VI. The competition was entered by a number of architectural and engineering firms. The winning design, by Faber Maunsell and Hugh Broughton Architects was chosen in July 2005.Halley VI was built in Cape Town, South Africa by a South African consortium. A total of 26 modular accommodation pods were added in total, installed in eight modules, which provides fully serviced accommodation for 32 people. The first sections were shipped to Antarctica in December 2007. It was assembled next to Halley V, then dragged one-by-one 15 km and reconnected.

Halley VI Station was officially opened in Antarctica on 5 February 2013. Kirk Watson, a filmmaker from Scotland, recorded the building of the station over a four-year period for a short film. A description of the engineering challenges and the creation of the consortium was provided by Adam Rutherford to coincide with an exhibition in Glasgow. A focus of the new architecture was the desire to improve the living conditions of the scientists and staff on the station. Solutions included consulting a colour psychologist to create a special colour palette to offset the more than 100 days of darkness each year, daylight simulation lamp alarm clocks to address biorhythm issues, the use of special wood veneers to imbue the scent of nature and address the lack of green growth, as well as lighting design and space planning to address social interaction needs and issues of living and working in isolation. Another priority of the structure construction was to have the least environmental impact on the ice as possible.

The British Antarctic Survey announced that it intended to move Halley VI to a new site in summer 2016–2017. A large crack had been propagating through the ice and threatened to cut the station off from the main body of the ice shelf, prompting the decision to move. This shifted the station 23 kilometres (14 mi) from its previous site, the first and as of 2020 only time the station has been moved since it became operational in 2012. Horizon, the long-running BBC documentary series, sent film-maker Natalie Hewit to Antarctica for three months to document the move. BAS completed the relocation of the base in February 2017.

Fig: 2: showing Antarctic Research Station Halley VI as it creates its own highway in the snow



Source: Posted by Anthony Davis Date: February 04, 2017
https://highways.today/2017/02/04/antarctic-research-station-halley-vi-creates-highway-snow/

Whilst the station was being relocated, concerns over another crack (dubbed the "Halloween Crack") emerged. This crack had been discovered on 31 October 2016, and now the BAS realized that it too could cut off the station, and possibly make it drift out to sea. Since evacuating the crew is all but impossible during winter, the BAS announced in March 2017 it would withdraw its staff from the base during March through October. Staff returned after the Antarctic winter in November 2017 and found the station in very good shape. As of 2020 the staff has been removed every winter since.

Fig: 3: Showing Engineering Design Concept

A test module erected during the 2008-2009 Antarctic summer proved the design and engineering concept as well as testing the performance of materials that were to be exposed to the extreme Antarctic winters.

Source: Posted by Anthony Davis Date: February 04, 2017
https://highways.today/2017/02/04/antarctic-research-station-halley-vi-creates-highway-snow/

Recommendations

It is recommended that the architecture used in Antarctica should be studies by experts in construction and building related endeavours to ensure humans can exist in environments even more alien than the South Pole, perhaps even allowing mankind to settle on other extreme parts of the world. The policy direction is that the Association of Architects in Nigeria should organize workshops and conferences that would help new architects become abreast with the various structural and building requirements needed for a sustainable architectural design in extreme environments that suffer desertification and water logged areas in Nigeria.

Conclusion

Mankind has never been complacent to just stay put, and exploration into the farthest reaches of our planet has resulted in human settlements in some seriously extreme locations. As a result, architecture has been forced to adapt to allow humans to live in such extreme conditions, and advances in technology have meant that mankind is able to live and explore even more remote and isolated environments. A million miles away from the tents and sleeping bags of Roald Amundsen and those with him who were the first to stand at the South Pole, modern architecture in Antarctica can be used as a model for how to adapt and live in such extreme conditions.

The architecture and technology used to create living and research centres in the most remote and inhospitable region on the planet shows just how adaptable humans are to living in extreme environments. They also have wider applications as the designs and ideas could be implemented to architecture in other locales affected by extreme weather. For instance, those areas affected by natural disasters such as earthquakes, hurricanes, tsunamis and tornadoes.

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