A Building for Testing European Rovers and Landers under Simulated Surface Conditions: Part 1 – Design and Phasing

David Nixon
Altus Associates architects

Truls Ovrum
Altus Associates architects

Copyright © 2008 SAE International

ABSTRACT

Europe has embarked on a new programme of space exploration involving the development of rover, lander and probe missions to visit planets, moons and near Earth objects (NEOs) throughout the Solar System. Rovers and landers will require testing under simulated planetary, and NEO conditions to ensure their ability to land on and traverse the alien surfaces. ESA has begun work on a building project that will provide an enclosed and controlled environment for testing rover and lander functions such as landing, mobility, navigation and soil sampling. The facility will first support the European ExoMars mission due for launch in 2013. This mission will deliver a robotic rover to the Martian surface. This paper, the first of several on the project, gives an overview of its design configuration and construction phasing. Future papers will cover its applications and operations.

INTRODUCTION

Europe is presently formulating plans for a new long range programme of Solar System exploration involving visits by European-built rovers, landers and probes to planets, moons and near Earth objects throughout the Solar System. In December 2005, European ministers approved the ExoMars mission – Europe’s first robotic exploration mission that will deliver a rover to the surface of Mars [ESA, 2005]. Other missions under consideration include a Mars sample return mission, a NEO lander mission, an asteroid sample return mission, a Deimos sample return mission, a further mission to Titan’s surface and a rover mission to one of the poles of Earth’s moon.

Rovers and landers will require extensive testing under simulated planetary, lunar and NEO conditions to ensure their ability to land safely, deploy, traverse the alien surfaces and take soil samples and analyze them on site or return them to Earth. Probes that utilize balloons or parachutes will also require surface proximity testing.

Basic rover, lander and probe concept development and testing work takes place at ESA’s Automation and Robotics Laboratory at the European Space Technology Centre (ESTEC) at Noordwijk in the Netherlands. Facilities at ESTEC are limited and ESA has decided to implement an expanded capability in the form of a purpose-designed environment for the development and testing of rovers, probes and landers with the emphasis on simulated surface operations. ESA has provisionally named the project as DOME (a facility for Design and Optimization of Moon/Mars Explorers). The purpose of DOME is to provide an enclosed and controlled volume and environment for testing functions such as landing, egress, mobility, navigation and soil sampling.

PROJECT DESCRIPTION

SITE - The project location is in the Netherlands at the town of Noordwijk on the coastline about 20 kilometres south of Amsterdam. The geographical area is flat with land elevations close to sea level and in some cases below it. The region is exposed to high winds from the North Sea and significant rainfall throughout the year, though winter temperatures rarely fall below freezing point. ESA has shortlisted several sites for DOME within and beyond the ESTEC campus. Of these, the site under consideration at the time of writing is at the eastern corner of the ESTEC campus.

Figure 1 shows a plan of ESTEC with the DOME site on the right in green. The site borders the ESTEC golf course to the south and a perimeter access road to the north-east. A large car park separates the DOME site from the main ESTEC buildings to the north-west. The site is relatively flat and presently used for garden
allotments and for outdoor storage of shipping containers. Figure 2 shows an aerial view of the ESTEC campus. The site is marked in blue with the car park above it and the golf course below it. A significant design challenge is rainwater disposal and the avoidance of flooding in a wet climate on ground close to sea level where there is a high water table. A rainwater retention pond, common in new developments in the Netherlands, will provide a landscaping feature next to the building. At the very top of the photograph are sand dunes which separate the campus from the seafront.

Figure 1 – Plan of ESTEC Campus

![Figure 1 – Plan of ESTEC Campus](image1)

PROGRAME - The initial accommodation programme comprises a range of facilities needed to enable full-scale and sub-scale rover, lander and probe development and evaluation. The building simulates planetary, lunar and NEO environments by replicating their surface and sky conditions for demonstration and testing of prototype or flight hardware. Past exploration shows that rover and lander interactions with alien environments is operationally complex, functionally constrained and subject to unplanned emergencies.

However sophisticated the analysis and design process such as the use of computerized tools for rover chassis design [Thuer et al. (undated); Richter et al., 2005], there are situations where testing and demonstration in simulated environments is essential. This is critical, for example, for rover terra-mechanical performance where the ability to negotiate and traverse a variety of surface features is vital to optimize a rover as a scientific research tool and ensure it can recover in terrain emergencies.

The main purpose of DOME is to provide an internal, environmentally controlled environment where simulated terrain, comprising geological features such as dunes, hills, cliffs, escarpments, fissures, craters, depressions, rock fields or even ice layers, occupies an area of sufficient size to permit effective hardware mobility testing. ESA estimates that a circular arena of 30 metres diameter with a clear height at the centre of at least half the diameter is needed to achieve these objectives.

Another important purpose of DOME is to provide lighting that simulates a variety of planetary, lunar and NEO conditions ranging from black sky and bright sunlight with crisp shadows on the Moon to a hazy brown twilight without shadows on Titan with Mars between the two extremes (lighting will be the subject of a separate paper). Reproducing the right lighting conditions – both surface and sky - is important for rover and lander optical and navigation systems testing from rover awareness of a particular horizon topography against a simulated sky accurately rendered from field data such as that from Mars [Maki et al., 1999], to the casting of shadows in the vicinity of rocks for depth perception during sampling operations.

Various facilities support the main testing arena. Chief among these are an airlock and a laboratory. Environmental control of the arena will ensure preservation of the simulated fine granular and powdery material of extraterrestrial terrain at the temperature and humidity needed for reproduction of its correct physical state. The airlock provides conditioning of outside air entering through an external door during vehicle or equipment ingress or egress before opening an internal door to the arena. The laboratory provide the means to prepare and service rover, lander and probe hardware before, during and after tests in the arena. Other
facilities include a workshop for crafting and fabricating terrain features, a visitor entrance lobby, viewing gallery, utilities rooms and personnel amenities. Table 1 summarizes the accommodation programme for the initial construction phases of the project – Phases 0 and 1. Additional accommodation can be added to DOME in future construction phases - Phases 3 and 4 - but requirements for these are not known at this time.

Table 1 – Summary of Architectural Programme

<table>
<thead>
<tr>
<th>ITEM</th>
<th>AREA (m²)</th>
<th>DIMENSIONS (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terrain Area</td>
<td>707</td>
<td>30 dia.x 21 h.</td>
</tr>
<tr>
<td>Perimeter Aisle</td>
<td>155</td>
<td>1.5m aisle width</td>
</tr>
<tr>
<td>Airlock</td>
<td>82</td>
<td>12 l. x 4 w. x 3 h.</td>
</tr>
<tr>
<td>Boiler/HVAC Rm.</td>
<td>53</td>
<td>7 l. x 7 w. x 3 h.</td>
</tr>
<tr>
<td>Cooling/Duct Rm.</td>
<td>53</td>
<td>7 l. x 7 w. x 3 h.</td>
</tr>
<tr>
<td>Visitor Corridor</td>
<td>93</td>
<td>3 wide</td>
</tr>
<tr>
<td>Interior Storage</td>
<td>36</td>
<td>7 l. x 7 w. x 3 h.</td>
</tr>
<tr>
<td>Exterior Storage</td>
<td>88</td>
<td>10 l. x 10 l. x 3 h.</td>
</tr>
<tr>
<td>Workshop</td>
<td>92</td>
<td>10 l. x 10 w. x 3 h.</td>
</tr>
<tr>
<td>Laboratory</td>
<td>50</td>
<td>7 l. x 7 w. x 2.5 h.</td>
</tr>
<tr>
<td>Switchgear Rm.</td>
<td>12</td>
<td>2.1 l. x 5.6 w. x 2.5 h.</td>
</tr>
<tr>
<td>I.T. Room</td>
<td>5.5</td>
<td>2.1 l. x 2.7 w. x 2.5 h.</td>
</tr>
<tr>
<td>Janitor Rm.</td>
<td>11</td>
<td>2.1 l. x 5 w. x 2.5 h.</td>
</tr>
<tr>
<td>Entrance Lobby</td>
<td>13</td>
<td>2 l. x 4 w. x 3 h.</td>
</tr>
<tr>
<td>Cloakrooms</td>
<td>24.5</td>
<td>2.5 l. x 3.3 w. x 2.5 h.</td>
</tr>
</tbody>
</table>

**DESIGN CONFIGURATION** - The major building element is a 30 metre diameter circular simulated terrain arena bordered by a 1.5 metre wide perimeter access aisle with both enclosed by a domed volume. The volume is slightly larger than a hemisphere with a clear internal diameter of 34 metres. The geometrical centre of the sphere is 4 metres above floor level, giving a clear internal height from floor to apex of 21 metres. The structural frame of the domed volume comprises 24 vertical steel lattice ribs approximately 0.95 metres deep placed at 15° intervals on plan and connected horizontally by inner and outer steel tubes formed into circular rings with diagonal steel bracing added as required. The lattice ribs converge at the domed apex and bolt to the floor into a perimeter concrete ground beam founded on a ring of concrete piles, the driven depth of which depends on local subsoil conditions. The floor is a reinforced concrete slab. It contains a 3 metre deep circular pit to enable excavation of simulated depressions and craters in the terrain. The pit will have the potential to function as a simulated water ice field when outfitted with an ice containment tank and mechanical refrigeration system. The domed skin consists of a profiled metal deck that follows the double curvature, an insulation layer and outer finish of colour-coated overlapping or standing seam metal sheets, fully sealed against wind-driven rainwater penetration.

An insulated metal deck roof with a polymer membrane or metal standing seam finish encloses the single storey peripheral facilities. Radial concrete block walls support the roof and follow the alignments of the steel lattice ribs. A glazed window wall encloses the peripheral facilities with a deep continuous roof overhang to provide shading. Figure 3 shows a diagrammatic plan and section of the building. The plan and section show the simulated terrain area in grey.

![Figure 3 – Building Plan and Section](image-url)
PHASING – The building will be built in several phases for two reasons: first, construction costs can stretch out to cover 2 or 3 years of ESA budget allocations; second, the design requirements and architectural programme for advanced mission testing beyond ExoMars are not precisely known at this time. Construction will consist of a maximum of 3 phases, of which Phases 0 and 1 are represented in Figure 3 and discussed in this paper. Phase 0 is a minimal initial phase which covers the installation of the spherical dome, the airlock and the HVAC systems; Phase 1 will introduce and add the first group of peripheral facilities.

Phase 2 will continue the peripheral facilities around the outside of the dome volume to the extent necessary. Figure 4 shows a construction phasing diagram.

CONCLUSION

The DOME Project will provide Europe with a specially designed building offering a controlled and conditioned environment for the testing and evaluation of rovers, landers and probes to be developed over the next decades under Europe’s space exploration initiative. The DOME building will be the first purpose-designed laboratory of its kind in Europe and an important addition to the family of laboratories and structures at ESTEC, ESA’s technology research and development centre in The Netherlands.

PROJECT TEAM


Project Manager: 4SPACE s.a.r.l., Paris, France.

Architects: Altus Associates, Los Angeles, California, USA.

Engineers: Arup, Cardiff, Wales, UK.

Cost Consultants: Davis Langdon, London, UK.

Cladding Design: Architecture + Vision, Rome, Italy.

REFERENCES


CONTACT

David Nixon, Altus Associates, at davidnixon@mac.com