

09:03 A Dozen Years to Make a State Go Virtual – LIDAR Data Use for 3D Visualisation of the Maltese Islands

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Abstract

Creating a new modus operandi for 3D data analysis that covers an entire state is an endearing task which required considerable funding and the integration of various thematic domains that lent an operational hand to spatial analysis in the Maltese state. An ERDF project taken up in Malta saw the integration of various environmental themes together with the creation of baseline surveys that serve the state as a launching pad for strategic analytical processes. The Malta study comprises the 3D component of the project which enabled the seamless integration of Terrestrial LiDAR, bathymetric LiDAR and bathymetric acoustic scans up to one nautical mile from the baseline coast, The aim of this process was to ensure that the integration of the datasets conformed to the requirements of the EEA (European Environment Agency) dataflow process (2012), the INSPIRE Directive (OJ, 2007), the Aarhus Convention (OJ, 2003a), the Freedom of Information Act (OJ, 2003b) and the Public Sector Information Directive (2003c). In addition, this project aimed to be the first to test the Shared Environment Information System (FORMOSA, SCIBERRAS, FORMOSA PACE, 2013; BORG, FARRUGIA, 2010).

1 Introduction

Nine years ago, embarking on a project to upgrade and enhance mapping in the Maltese Islands was deemed as a veritable cliff-hanger decision if not a potentially impossible-to-manage project. Perseverance and a drive to tackle the different data sources in a holistic approach has resulted in the capture of a nationwide series of datasets and information systems, which systems would deliver a new modus operandi for spatial analysis in the Maltese state. The aim was to base the whole process on the integration of the requirements of the EEA (European Environment Agency) dataflow process (2012), the INSPIRE Directive (OJ, 2007), the Aarhus Convention (OJ, 2003a), the Freedom of Information Act (OJ, 2003b) and the Public Sector Information Directive (2003c). In addition, this project aimed to be the first to test the Shared Environment Information System (FORMOSA, SCIBERRAS, FORMOSA PACE, 2013; BORG, FARRUGIA, 2010).

The project¹ was also aimed at creating an effective tool for the monitoring of and reporting of environmental information in the air, water, noise, radiation and soil domains, which

¹ Following an extensive analysis of the requirements for spatial data enhancement in the physical, social and natural environments, the Maltese Islands are in the final stages of acquiring a comprehensive set of data that will serve as a basis for cross-thematic research. This is being made possible through the creation of fundamental datasets that will bring Maltese terrestrial and

outputs would have ensured the creation of baseline studies for future trend analysis (MALTA ENVIRONMENT AND PLANNING AUTHORITY, 2009).

The results have yielded international feedback (Martirano, Bonazountas, Formosa, Nolle, SCIBERRAS & VINCI, 2012) at the INSPIRE 2012 Conference and at the ELMF 2012 LIDAR² Mapping Forum (HOFFMANN, FORMOSA, SCIBERRAS, ALBERTS & VAN DER VEGT, 2012), with outputs breaking some records on data returns. This paper concentrates on the 3D data deliverables emanating from this process in 3d employing high resolution data emanating from the ERDF project.

2 Processes and Methods

2.1 Input Data and Technologies

The project delivered terrestrial and bathymetric data at high resolutions suitable for detailed environmental modeling and for EU reporting purposes. Dealing with the dearth of information that is currently the status in both academia and in the industry, which situation hinders comprehensive land use planning, environmental monitoring and the resultant socio-security impacts, the project takes into account the various dataset requirements to ensure an overarching approach to analytical research and legislative implementation.

Due to the various national/EU environmental obligations, MEPA is committed to upgrade Malta's environmental regulatory capacity, including efforts to ensure full compliance with relevant Community Directives as well as national legislation. However, environmental monitoring and reporting is hampered by an incomplete monitoring strategy, lack of baseline environmental data on ambient conditions, lack of monitoring infrastructure and modern monitoring equipment and limited human resources. The project was aimed at ensuring the enhancement of national monitoring programmes in the five environmental themes through the identification of information gaps in monitoring processes and filling data gaps, the carrying out environmental baseline surveys, the procurement of monitoring equipment & information management systems and the training of experts. Each of the main five domains identified were investigated in depth for their data dearth's.

This is especially true due to a lack of high quality 3D spatial data, where the need was felt to commission such a project that covered the terrestrial area up to 1 nautical mile from the baseline coast (Figure 1a), the marine area registering a depth of 0-15m (Figure 1b) and the bathymetric area up to 200m depth (Figure 1c).

bathymetric baseline free information to the public domain. Such was made possible through an initiative as part of a €4.6 million project, entitled Developing National Environmental Monitoring Infrastructure and Capacity, which involves monitoring of air, water, soil, radiation and noise and 3D terrestrial and bathymetric surveys. This project co-financed by the European Regional Development Fund, which provides 85% of the project's funding and the Government of Malta, which finances the rest under Operational Programme 1 – Cohesion Policy 2007-2013 – Investing in Competitiveness for a Better Quality of Life.

² Light Detection and Ranging (LiDAR).



Fig. 1a: Terrestrial Area and baseline coast up to 1 nautical mile

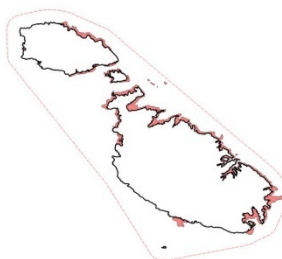


Fig. 1b: Coastal water areas of depths between 0m to 15m



Fig. 1c: Coastal zone of depths between 15 m to 200m

The data incoming from the project included a high resolution 3D terrestrial data coverage for the Maltese Islands using a combination of oblique aerial imagery (Figure 2) and Light Detection and Ranging (LIDAR) data (Figure 3), as well as through a bathymetric survey of coastal waters within 1 nautical mile (nm) radius off the baseline coastline, using a combination of bathymetric LIDAR surveys (Figure 4), acoustic scans and a physical grab sampling survey (Figure 5). These outputs, together with other fieldwork technologies as are handheld scanners and GIS handhelds, aid the researchers with a launching pad for the diverse physical, environmental and social studies that are undertaken in relation to the strengthening of social and environmental fabric. The basis for the future analysis of the multi-thematic analysis was laid through the acquisition of various deliveries that include the following 5-point outputs by technology, delivery and area:

- LIDAR Scan: Terrestrial (Topographic Light Detection and Ranging (LiDAR)) Digital Surface Model (DSM) and Digital Terrain Model (DTM) (316 km.sq).
- Bathymetric LIDAR aerial survey – depths of 0 m to 15m within 1 nautical mile from the Maltese coastline (38 km.sq).
- Bathymetric Scan: Acoustic (side scan sonar). Digital Surface Model and an acoustic information map of sea bed (361 km.sq).
- High resolution oblique aerial imagery and derived orthophoto mosaic and tiled imagery of the Maltese Islands (316 km.sq).
- Satellite imagery (GeoEye, RapidEye, Quickbird) (316 km.sq).



Fig. 2: Satellite and oblique imagery



Fig. 3: LiDAR data

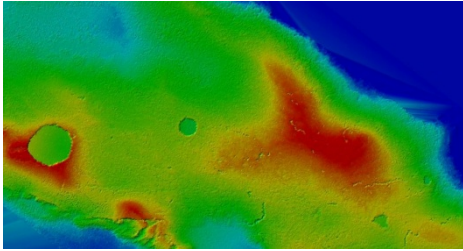


Fig. 4: Bathymetric LiDAR data

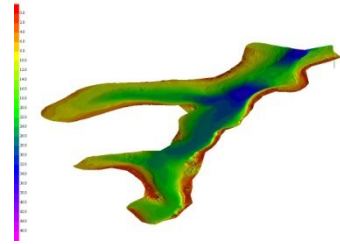


Fig. 5: Acoustic Scan data

2.2 Modelling approach

Malta's target to acquire LIDAR scans as well as a full bathymetric survey has been carried out for all the Maltese terrestrial areas and the coastal waters. Whilst various terrestrial exercises were carried out for development planning and environmental protection purposes, various bathymetric surveys were carried out for specific projects and research work, however, the latter were ad hoc and highly localized with rare attempts at a strategic methodology.

Mapping the terrestrial and seabed topography has various applications. It will provide a basemap from which various environmental studies can be carried out. These include studies as required by the Corine Landcover Initiative, the Water Framework Directive and the Marine Strategy Framework Directive which are aimed to protect more effectively the territorial landmass and the marine environment and in turn effect the health of the region's population. It will also serve as a tool for impact analysis of development planning, pollution and chemical prediction modeling, climate change monitoring as well as render recognition of features. It will also serve to aid enforcement officers to analyse the trends in security breaches and illegal development as well as plan for potential health hazards. In addition, it will allow thematic experts to study, monitor, analyse and protect those areas that are vulnerable to degradation and exposure. Spin-offs from the results include updated nautical charts, viewshed analysis and cross-thematic studies in the physical, social and environmental domains.

The 3-D aerial surveys using Lidar technology surveys were carried out by the main contractor TerraImaging, whilst the aerial Lidar bathymetric scan was carried out by Peldryn (UK) and the vessel-based bathymetric surveys are carried out by AquaBioTech Group. Following these aerial surveys, users will be able to generate digital terrain 3-D models which can be used for various applications such as urban and transport planning, environmental impact assessments, infringement analysis, security review, modeling of runoff water, monitoring of and enforcement of land use activities, amongst others.

The original terrestrial LiDAR scan was targeted at acquiring a minimum of 1 point per square meter but resulted in a 4.3 point per meter square outcome, which resulted from the use of an AGL Sensor: IGI Litemapper 6800 (Riegl 680i) at a Fh of 950 m. The acquisition was carried out together with the simultaneous image acquisition of a mosaic with GSD of 16cm employing and IGI DigiCam. The DSM and DTM outputs at 4.3 Pts/m² had a height accuracy of >5cm.

The bathymetric LiDAR employed a HawkEye IIb (AHAB), operating at frequencies of 1Khz for the bathymetric areas and at 8Khz for the topographic areas. What is unique in the Malta scan is that the bathymetric LiDAR achieved higher depths than the 15m designated for the project and achieved reliable returns at 50m depths.

The bathymetric acoustic scans were carried out using sidescan sonar with main issues encountered related to unstable weather, turbidity, high waves and wind. Ground truthing of bathymetric surveys was carried out to determine the type of sea bottom, whilst grab sampling samples are taken where the ground changes. Accuracies were achieved as per IHO requirements.

The oblique imagery and Orthoimage mosaic had a resolution of 15cm and an accuracy of $\pm 1-2$ pixels. The technology used was through a VisionMap A3 Camera, where more than 2000 photos were taken to cover the islands at a Fh of 3000m.

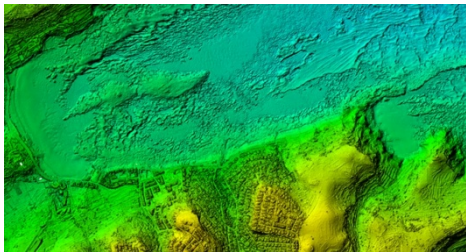


Fig. 6: Seamless LiDAR integration

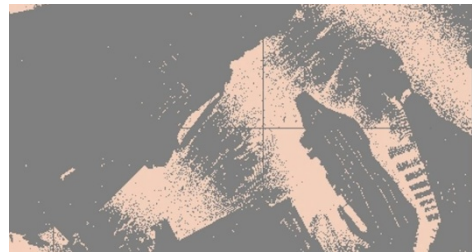


Fig. 7: DEM

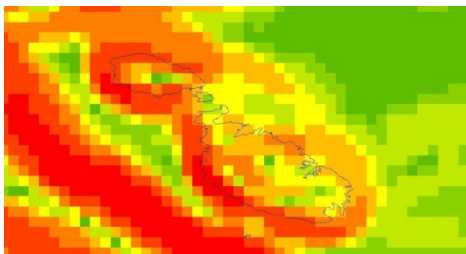


Fig. 8: Slope analysis

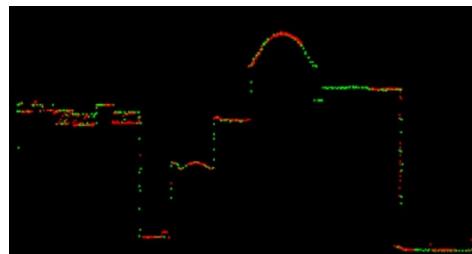


Fig. 9: Cross-Sectional analysis

Merging the three scans together proved challenging (Topographic LiDAR data + Bathymetric LiDAR data + Vessel bathymetric data) due to the varying coverage (data overlaps), data accuracies ranging from 5-50cm RMS varying by depth, as well as the different acquisition windows for the three technologies. TerraImaging carried out an advanced interpolation technique that allows one to weigh the different properties of the data sets (e.g. accuracy, resolution). This resulted in a seamless transition (Figure 6) where shallow areas the data fitted very well (within 10 cm) with clear data boundaries of each data source being defined and systematic effects being detected and corrected (ALBERTS, 2012).

The results show that as the data is integrated into one system, the outputs aid the researchers to carry out detailed analysis such as the identification of vulnerable areas affected by climate change. This includes analysis of marine and urban areas that will be effected due to their topographic location using integrated LiDAR datasets (figure 6), building Digital Elevation Models of the zones and the infrastructure in order to identify those areas that could for example experience sea-level rise (Figure 7), employing height/depth interpolation and slope analysis (Figure 8) as well as carrying out cross-sectional analysis of infrastructure (figure 9). These initial outputs show that with the setting up of an integrated system which adheres to official environmental requirements, results are readily available, pending the further scenario testing as new knowledge is made available.

3 Results

Deliveries included a terrestrial LIDAR Scan (Figure 10) which resulted in a baseline map for the Maltese Islands infrastructure and landcover/landuse analysis which is required for the monitoring of structures that impact on noise levels, enforcement issues, resource monitoring and risk prediction, amongst others.



Fig. 10: Integrated Terrestrial and Bathymetric Data

The bathymetric LIDAR aerial survey for depths of 0 m to 15m (Figure 10) and the ship-based bathymetric scan will enable the creation of new nautical charts as well as bathymetric outputs that will help in marine spatial planning.

3.1 Initial Analytical Outputs and Dissemination

An analytical process has been initiated to develop the first strategy maps and tools for policy and decision makers. The contouring of the bathymetric data in the vicinity of the Azure Window in northwest Gozo has resulted in the identification of anomalous structures that are too linear to be natural and are being further investigated (Figure 11). In addition, the use of a 3D printer, resultant from the same project has enabled the decision makers to objectively visualise potential developments prior to their being approved as against potentially subjective photomontages (Figure 12). This data was also enhanced using landscape renderers such as Bryce resulting in a photo-realistic interpretation of the area under study, in this case the Dwejra Cliffs in Gozo (Figure 13).

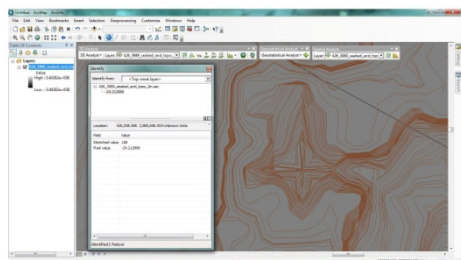


Fig. 11: Satellite and oblique imagery

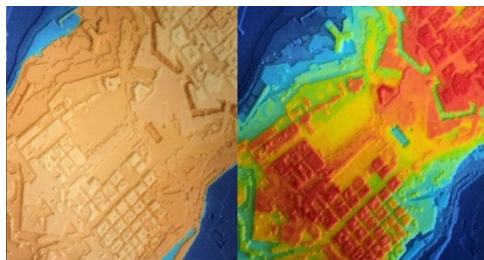


Fig. 12: 3D printing of models

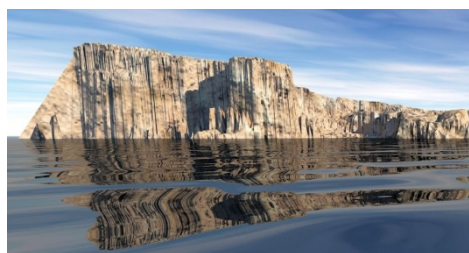


Fig. 13: Landscape rendering

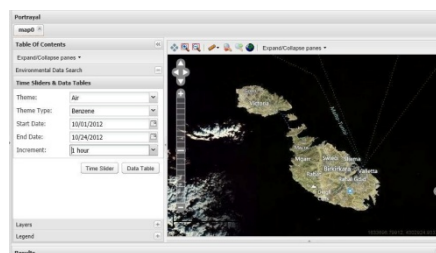


Fig. 14: SEIS interface

An interesting study that was also carried out on the initial data refers to the integration of the project data with data from international sources (Global Elevation Data extracted from dataset *ETOPO1_Ice_c_Geotiff1.tif*³, Coastlines: *GSHHS* dataset⁴, and country administrative regions: *gntlnbnds.shp* (created by the Global Rural-Urban Mapping project,

³ 1 arc-minute global relief model of the Earth's surface that integrates land topography and ocean bathymetry. Grid of the Earth's surface depicting the top of the Antarctic and Greenland ice sheets. www.ngdc.noaa.gov/mgg/global/relief/ETOPO1/data/ice_surface/grid_registered/xyz/.

⁴ Global Self-consistent Hierarchical High-resolution Shorelines version 2.0 July 15, 2009, WESSEL, P. & SMITH, W. H. F. (1996), *A global, self-consistent, hierarchical, high-resolution shoreline database*. In: *J. Geophys. Res.*, 101 (B4), 8741-8743.

Version 1 (GRUMPv1) National Administrative Boundaries⁵). The study sought to understand the extent of the Maltese landmass in ancient periods, circa 12,000 years in the past when the waters from the glacial period had yet to melt and subsequently submerge the land between Malta and Sicily eventually rendering the Maltese Islands into its current form (Figure 15).

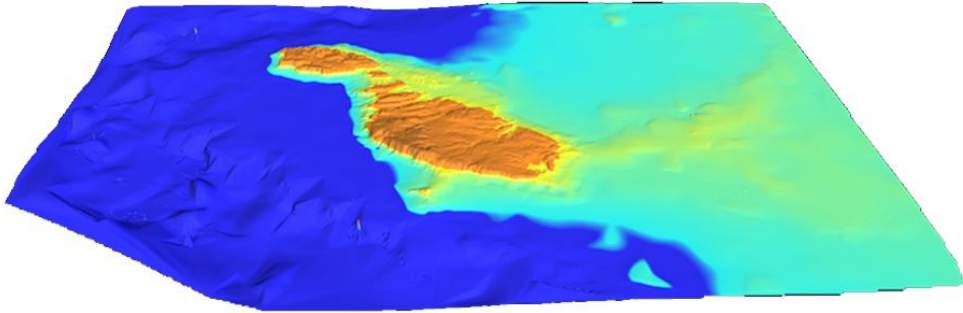


Fig. 15: Ancient Maltese Landscapes: Pre-Glacial Melting circa 12,000 Years Ago

In terms of dissemination of the results, the project, having been structured around a number of international directives, aimed to ensure the free delivery of all data to the general public. This was the result of an integrated exercise to adhere to the requirements as outlined by the Commission’s Communication COM (2008) 46 Final “Towards a Shared Environmental Information System”, the INSPIRE Directive (Directive 2007/2/EC) and the Aarhus Convention.

All data from this project is being made viewable and disseminated through a web portal, currently being designed, known as a Shared Environmental Information System (SEIS) (Figure 14).

4 Conclusions and Outlook

Scanning technologies may yet make inroads in the social and planning operational fields that have to date been reluctant to take up the outcomes of the spatial technologies. However, the Maltese scenario is ripe to take off through the employment of the various 3D technologies employed through the ERDF156 project. The terrestrial LIDAR scan combined with the bathymetric acoustic scan up to 1 nautical mile from the baseline coast and the inclusion of bathymetric LIDAR ensure seamless analysis of both domains. Combined with oblique imagery takes and in-situ data trawling, the end result has enabled

⁵ Center for International Earth Science Information Network (CIESIN), Columbia University; International Food Policy Research Institute (IFPRI); the World Bank; and Centro Internacional de Agricultura Tropical (CIAT). 2011. Global Rural-Urban Mapping Project, Version 1 (GRUMPv1), National Administrative Boundaries. Palisades, NY: Socioeconomic Data and Applications Center (SEDAC), Columbia University.
<http://sedac.ciesin.columbia.edu/data/dataset/grump-v1-national-admin-boundaries> (June 2012).

the production of a unique model of the islands for use across the scientific platforms. The free dissemination of the data through Aarhus-compliance to the general public and the scientific community should enable the launching of integrated research across the spatial and social themes. Urban and environmental planners can undertake urban modeling scenario-building for strategic, regional and local areas, with the add-on integration of social, economic and criminological issues leading to healthier and safer localities. In addition, the data can be integrated with impact-analysis of baseline studies for air, water, noise, soil and radiation themes and their impacts on high population/urban density Malta.

The paper investigated the process taken to implement such a multi-tech process, the proposed data integration processes and the eventual studies that will be launched to ensure sound urban, social and environmental studies over the next decade. Together with such technologies as remote GPS cameras, 3D scanners and mobile GIS handheld loggers as well as other spatial data trawlers, the future for landscape assessment will be drastically enhanced in terms of provision of data and analytical information resources.

Nine years in the making, but the most crucial will be the next three years were the data will be integrated into a wide range of systems as disseminated to the public and private arenas as well as the non-governmental organisations. The technology required to analyse the massive volumes of data may not be available to all but with open-source applications and access to hardware from the University of Malta and the environmental agency, such analysis would be made possible.

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