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**Geological Survey of Ireland Research Programme
- Short Call 2015, Final Report -**

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Organisation name	Greenlight Surveys Ltd
Organisation type:	☐ HEI ☐ Public Sector (other) ☒ Private Sector
Department/section	Survey Operations

Project Title	UAV for Inter-tidal and Coastal Zone Mapping
Contract No.	2015-sc-031



Project Report (max 1500 words, excluding figures and headings):

- (i) Objectives and scientific/engineering targets beyond the state of the art

Project aim:

To Investigate the feasibility of operating a UAV based service for Coastal Zone Mapping

Project objectives:

- 1) Ascertain the regulatory requirements for UAV operations in the coastal zone.
- 2) Survey the intertidal zone of an INFOMAR bay generating sufficient data for study
- 3) Investigate data processing requirements, software and methodologies
- 4) Collate findings into final report and supplementary documentation.

This project benefited from the availability of a high performance survey drone – a Trimble UX5HP which was procured by Geological Survey Ireland and made available to the project to underpin the feasibility study and to expedite capacity building in this area.

A consequence of this was that the scope of the project was broadened to incorporate additional geoscience mapping applications/activities undertaken by Geological Survey Ireland to those of the INFOMAR programme. As Geological Survey Ireland became committed to operating at least one survey grade UAV in support of its activities the focus of this project evolved beyond determining the feasibility of applying UAV technology for coastal mapping operations to incorporate terrestrial surveys. It should be stressed that all four objectives specific to the INFOMAR programme were successfully and adequately addressed throughout the course of this project.

An outcome of the necessity to build the Trimble UX5-HP UAV into the project was that the workflow evolved along a different trajectory to the four phase pathway outlined in the project proposal: The original project milestones were as follows:

Project Milestones

- 1) Training and Preliminary Standard Operating Procedures
- 2) Data processing and handling strategy
- 3) Final Standard Operating Procedures
- 4) Delivery of survey data and final report

All project objectives and milestones were achieved however the necessity to develop actual capability/capacity rather than simply report on requirements resulted in some delays or deviations from the planned implementation. Overall the workflow undertaken by the project was of far greater substance and value than the proposed investigations, resulting in a significant increase in Geological Survey Ireland's/INFOMAR's mapping capabilities. It also significantly developed Greenlight Surveys' knowledge, expertise and capability to provide services and generated valuable datasets tied to several geoscience projects currently underway or recently completed. The process undertaken in order to build this capacity required that objectives 1, 2 and 3 were of critical importance and could not have been delivered without achieving milestones 1, 2, and 3 in that order as listed above. Objective 4 and Milestone 4 are the outcome of assessing and evaluating the processes undertaken throughout the project and are the tangible record of the knowledge and data generated throughout the course of this project.

Progression beyond state of the art

The project set out to establish the feasibility of applying UAV photogrammetry for mapping coastal and intertidal areas in support of INFOMAR. To achieve this aim and progress beyond state of the art the following criteria needed to be met:

- 1) Regulatory and Licensing requirements had to be delineated/established
- 2) Survey data from an INFOMAR intertidal zone had to be acquired for evaluation
- 3) RTK/PPK capability/reliability had to be demonstrated in the “Z” frame of reference
- 4) Data processing requirements needed to be established and validated for INFOMAR programme
- 5) A report compiled describing the feasibility of implementing the technology at a range of scales

The added requirement to develop full capacity for implementing UAV surveys using Geological Survey Ireland’s Trimble UX5-HP UAV ensured that all regulatory and licensing requirements had to be established prior to IAA testing and certification. This was carried out successfully, albeit with some delays associated with scheduling. The result is a comprehensive understanding of training, regulatory and licensing workflows. Once fully operational the focus fell on data acquisition and development of data processing procedures. Table 1 presents key datasets developed during the project. Surveys often incorporated multiple flights and data generated were supplied to the relevant parties once processed.

Location	Group	Concepts tested
Cahore, Co. Wexford	INFOMAR	CGP accuracy, Beach Profiling, Flight over water
Murvey Peninsula, Co. Donegal	INFOMAR/UCD	Intertidal Zone, Beach Area, CGP accuracy, emergency procedures, dune geomorphology, coastal erosion
Turlough, Co. Roscommon	Groundwater	Lake water level mapping
Turlough, Co. Galway	Groundwater	Lake water level mapping, GCP accuracy
Shanballymore, Co. Cork	Groundwater	Karst feature identification, Camera Mode
Youghal, Co. Cork	INFOMAR	Weather tolerance, abandoned
Clifden, Co Galway	Landslide Project	Landslide mapping, volume estimation
Kenmare, Co. Kerry	INFOMAR	Collaboration with BIM for aquaculture project

Table 1: Significant datasets delivered

Survey work and subsequent data processing undertaken during the latter half of this project resulted in the development of robust data acquisition and data processing techniques. Each survey set out to provide answers to questions raised by previous operations. In this way the project achieved all of the scientific and engineering targets set out at the beginning. The SOTA was further advanced by implementing the following two adjustments to the project workflow and budget.

- 1) Due to the extension of the project’s scope which negated the requirement to acquire topographic data using third party consultancy, the decision was made (between GLS and INFOMAR supervisors) to modify the budget to incorporate further third party data acquisition using complementary sensors including thermal, multi-spectral and near-infrared so that use these data types and sensors may be assessed.
- 2) In order to add further value to the high resolution/accuracy DSMs and orthomosaic imagery produced by Geological Survey Ireland’s UAV, specialist classification/mapping software was acquired to determine the limits of useful geospatial information which may be extracted from the various data.

(ii) Implementation (including reference to timelines, milestones, management)

Timeline	Key Reference
January	Literature review, planning, groundwater meeting, INFOMAR Kick Off meeting
February	Operator and Ground-school Training completed, UX5HP damaged
March	Repaired UX5 HP flight tested at Newcastle aerodrome,
April	Development of operations manual, Insurance, Registration
May	IAA review of ops manual, specific operating permission testing, pilot testing
June	IAA approval for range extension, pilot certification and specific operating permission. Mission Planning
July	Survey Operations, development of DP methodologies
August	Survey Operations, development of DP methodologies
September	Survey Operations, development of DP methodologies
October	Survey Operations, development of DP methodologies
November	Survey operations, conference presentation, conference workshop, eCognition workshop, DP appraisal and training methodology.
December	Final reporting / collation of knowledge developed

Table 2: Project timeline

Table 2 offers a generalised overview of the project timeline. Initially the project progressed along a different development trajectory than originally planned, with the focus firmly set on developing operational capability from January through to June 2016. After achieving operational status, survey data were acquired on a systematic basis in line with a developing DP (data processing) methodology and the data requirements of Geological Survey Ireland. Regular verbal updates were provided to the INFOMAR project supervisor. Project results were presented in November at the annual INFOMAR seminar and a one hour workshop was presented at the Trimble Dimensions conference in Nevada. While there

Some of the management challenges encountered over the course of the project are listed below:

- Operator training and familiarisation with the newly acquired UAV asset had to be undertaken
- The equipment suffered some damage during training (covered and repaired by manufacturer)
- IAA ground school training had to be undertaken and certification acquired
- Flight testing with a licensed operator had to be undertaken to acquire sufficient flying time
- An operations manual covering the every aspect of UAV operations, safety and policy had to be developed on behalf of Geological Survey of Ireland.
- An IAA exemption to the allowable range for flying the UX5-HP had to be assessed and accepted.
- IAA Approved flight testing for specific operating permission had to be passed and forms submitted to IAA – there was a delay associated with receiving certification
- Commitments of project lead to INFOMAR seabed mapping operations
- The Trimble UX5-HP is a delicate piece of equipment and difficult to land in certain conditions
- Evaluation of data processing techniques was considerably more complex than originally envisioned.
- Initially workstations struggled with the volumes of data being generated – problematic until final settings and parameters were arrived at.
- A fixed wing solution could not be deployed at all locations visited.
- Data from additional sensors are not currently available due to scheduling constraints. These important datasets will be included in a future version of the project's feasibility study report which covers these challenges in more detail.

(iii) Outputs (please use bullet points)

- Delineation of licensing, regulatory and training requirements
- Fully trained and licensed Chief Pilot for Geological Survey's UAV
- Registration, licensing and Permission to Operate for Geological Survey Ireland's UAV
- IAA Approved Operations Manual and Risk Assessment for Geological Survey's UAV
- IAA Approved range extension for operations in Inter-tidal areas
- Standard Operating Procedures for UAV operations on behalf of Geological Survey
- Support hardware and maintenance strategy for Geological Survey's UAV.
- Evaluation of PPK concept for operations independent of Ground Control Points (GCPs)
- Accuracy assessment complete
- Data processing methodology (compatible with INFOMAR workflows)
- Data handling and integration methodology
- Report of Survey Template
- INFOMAR survey data
- Survey data for coastal, landslide, groundwater and karst feature mapping projects
- Survey data for the appraisal of complementary sensors (pending)
- Software licences data for processing and development of value added products.
- Full data processor training and software appraisal
- Survey data to support MSc dissertation
- Conference presentation (INFOMAR) and conference workshop (Trimble Dimensions)
- Feasibility Study Report

Impact/value of the project (Max 500 words):

Feasibility Study

The technology and method has been determined to be feasible although the scale at which it can be deployed is still a question which requires more work. Geological Survey of Ireland is a fully licensed operator capable of implementing topographic survey operations at +/-3cm accuracy – a significant increase in capability. Greenlight Surveys Ltd has development significant expertise in this field.

Asset Acquisition

As a result of work carried out on this project Geological Survey Ireland have committed to the procurement of a SOTA UAV with Vertical Take Off and Landing capability. The organisation has also committed to procurement of inspection/survey/video UAV and a SOTA thermal imaging camera for groundwater mapping operations.

Development of Commercial Service

Greenlight Surveys Ltd has also procured a small professional UAV for video and 3D modelling applications. This was possible due to the knowledge developed over the course of this project.

Further Research

This project has established the feasibility of an organisation or programme such as Geological Survey Ireland or INFOMAR undertaking UAV borne mapping operations. It has engaged other sections and projects within Geological Survey Ireland and set the scene for further research and development work.

Training

A comprehensive training programme will developed from the knowledge generated through this study.