The river runs through IT

SLOVENIA HAS BEEN USING AGILE MICROSATELLITES TO BUILD HIGH-QUALITY DIGITAL TWIN 3D MODELS OF RIVER BASINS. BY **KEVIN P CORBLEY**

Several years ago, Slovenia recognised the potential for small-satellite technology to revolutionise earth observation (EO) and established SPACE-SI – the Slovenian Centre for Excellence in Space Sciences and Technology – in Ljubljana with plans to build the country's first microsatellite. In 2020, SPACE-SI launched NEMO-HD, a versatile remote sensing microsatellite about the size of a suitcase and costing a fraction of a traditional EO satellite.

That bet on microspace technology has paid off. Over the past three years, NEMO-HD has proved its mettle by capturing 2.8m resolution pan-sharpened multispectral imagery and high-definition video for a variety of scientific and commercial applications, often partnering with the European Space Agency (ESA) on global projects. In-country, the microsatellite has responded to the devastating 2022 Kras wildfire and deadly August 2023 floods.

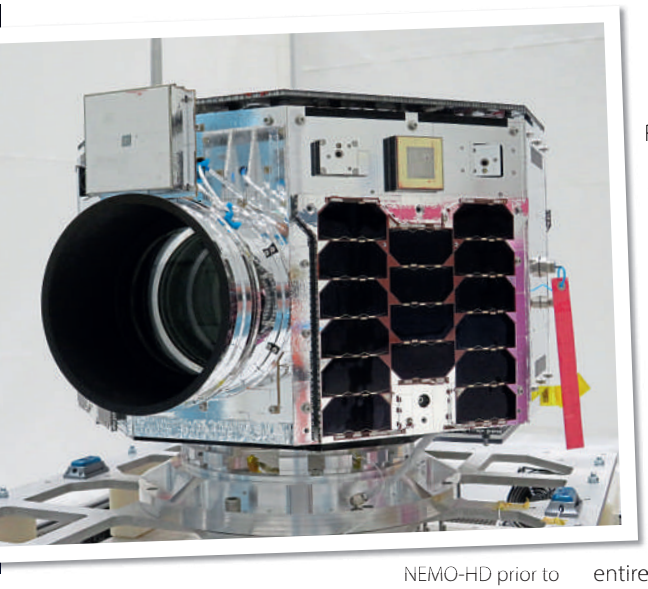
In terms of non-emergency applications, NEMO-HD has assisted SPACE-SI and C3M – a Slovenian computer modelling company – in making a name for themselves by developing high-quality 3D 'digital twin' models of river basins by combining Sentinel imagery with agile NEMO-HD acquisitions. Used worldwide, these 3D river models will be instrumental in balancing the often-conflicting activities of economic development and environmental sustainability.

In addition to joining forces with C3M modelling experts, SPACE-SI credits much of its river mapping success to the agility of the spacecraft, which enables it to acquire imagery of long river segments on a single pass in one day – even if the basin flows perpendicular to the satellite's north-south orbital path. The onboard attitude control that makes orbital manoeuvrability and precise sensor pointing possible is a breakthrough small satellite technology developed with Space Flight Laboratory (SFL) of Canada.

Building a river's digital twin

A digital twin is a 3D model of a geographic area that is both visually realistic and geometrically accurate. Unlimited layers of geospatial data can be added to the digital twin, not only to monitor and visualise existing conditions but also to simulate and predict future scenarios. On its river models, for example, SPACE-SI is adding data sets related to vegetative cover, soil moisture, water quality and other factors critical to analysis and management of riparian ecosystems.

The most important layer of the digital twin is the base map, which SPACE-SI is creating from the multispectral NEMO-HD imagery. The quality of the base layer directly determines the accuracy of the monitoring and simulation applications performed with the digital twin. Capturing the base imagery in a single satellite



NEMO-HD prior to integration with the launch vehicle in Kourou, French Guiana, in January 2020. © SFL

pass significantly enhances the overall quality and consistency of the data because each image scene is acquired under nearly identical atmospheric and ground conditions.

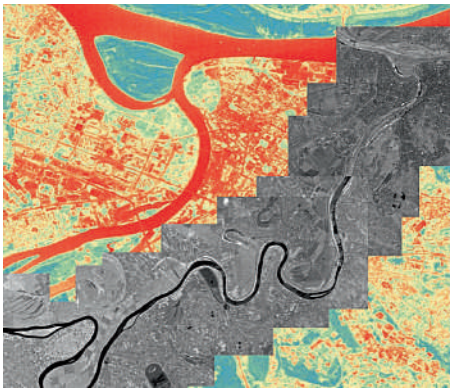
"Imaging long stretches of north-south running rivers is relatively easy because they roughly coincide with the track of the satellite's polar orbit," explained Dr. Tomaž Rodič, SPACE-SI director. "But east-west rivers are more challenging because they require the satellite to slew from side to side so the sensor can point across track."

Despite the challenge, the achievements of SFL-developed technologies were extremely effective. SPACE-SI participated in a demonstration project with ESA to create digital twins of the Sava and Danube Rivers in Central Europe and Ganges River in India. These rivers each trend roughly east-west but with north-south segments as well, adding challenge to the acquisitions.

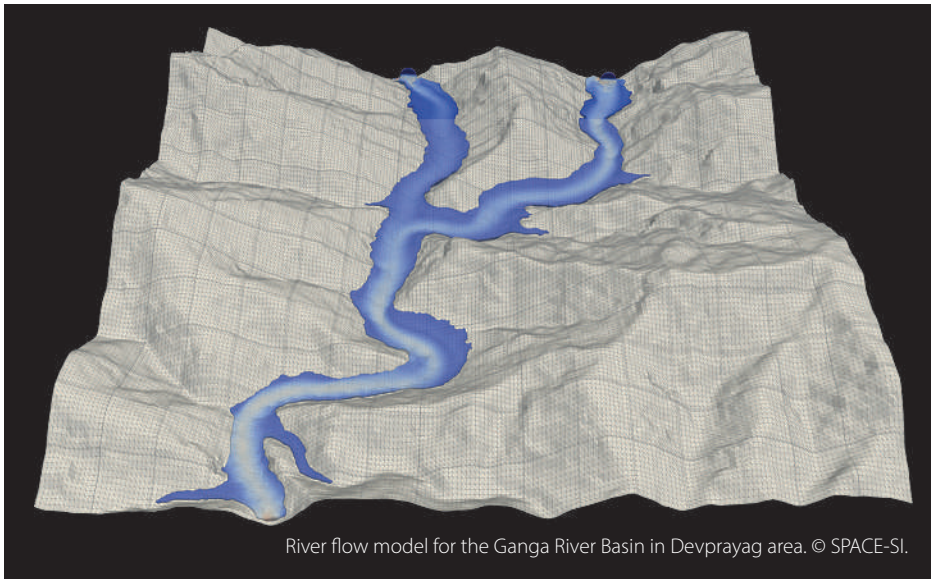
Depending on the geometry of the river, NEMO-HD can capture about 600km of cross-track imagery in one pass, explained Rodič. However, the weather was an important factor to take into account to ensure production of a high-quality base map. For the 950km Sava River, SPACE-SI planned each day's satellite tasking to capture segments with minimal cloud cover, mapping the entire extent in five passes. The longest east-west river basin imaged in a single pass was a 290km stretch of the Danube between Vienna in Austria and Budapest in Hungary.

NEMO-HD captured same-pass high-quality imagery for similarly extensive segments of the Ganges in the GangaSat project. The success merited SPACE-SI an invitation from India to participate in a soon-to-be-announced effort to create 3D digital twins for many ecologically and economically important stretches of 22 of the most important rivers in the world.

NEMO-HD CAN ACHIEVE THE SAME IMAGING OBJECTIVES AS MUCH LARGER SATELLITES, BUT AT 10–20 TIMES LOWER COSTS



Satellite scanning of transboundary Sava River by NEMO-HD from its sources in Slovenia to the confluence with Danube River in Serbia. © SPACE-SI



River flow model for the Ganga River Basin in Devprayag area. © SPACE-SI.

Attitude is crucial

NEMO-HD's agility in orbit enables it to slew fore and aft and side to side rapidly while capturing hundreds of overlapping images covering large geographic areas. Just as important, however, is the satellite's stability which enables the sensor to accurately point at ground targets and acquire sharp, geometrically precise images. Attitude control is the technology that governs spacecraft pointing, stability and agility.

"Accurate, precise and agile attitude control is essential for smaller satellites to be used in demanding applications," said SFL director Dr Robert E Zee. "SFL is one of the only small satellite developers that actually delivers on its promise of outstanding pointing for the most challenging missions in the world today."

SFL was established in 1998 to deliver quality small satellites with outstanding attitude control to the world. The Toronto satellite provider continually develops and refines cutting edge stabilisation technologies involving miniaturised sensors and actuators managed by onboard algorithms. Since its establishment, SFL has built 70 operationally successful microspace satellites – some as small as shoeboxes – for dozens of commercial and scientific missions with demanding and often unprecedented requirements. Many required stringent pointing and/or tracking of sensors for Earth observation, atmospheric monitoring, and space astronomy.

"NEMO-HD can achieve the same imaging objectives as much larger satellites, but at 10–20 times lower cost," said Zee. "This combination of utility and cost-effectiveness makes microspace Earth Observation programmes attractive to organisations like SPACE-SI that want guaranteed accessibility to imagery from their own assets in orbit."

A constellation of SmallSats

Through its river basin digital twin work, SPACE-SI and C3M have partnered with organisations throughout Europe, Asia, Africa, Latin America and Caribbean countries. The company expects the upcoming 22 Rivers Project – which will involve construction of a NEMO-HD receiving station global network – to highlight the utility of 3D digital twin models in sustainable monitoring and management of river basins.

SPACE-SI's Rodič believes the programme could form the foundation for a global consortium of small satellite operators monitoring the world's rivers on a daily basis – and accomplishing a variety of other applications – with agile spacecraft similar to NEMO-HD.

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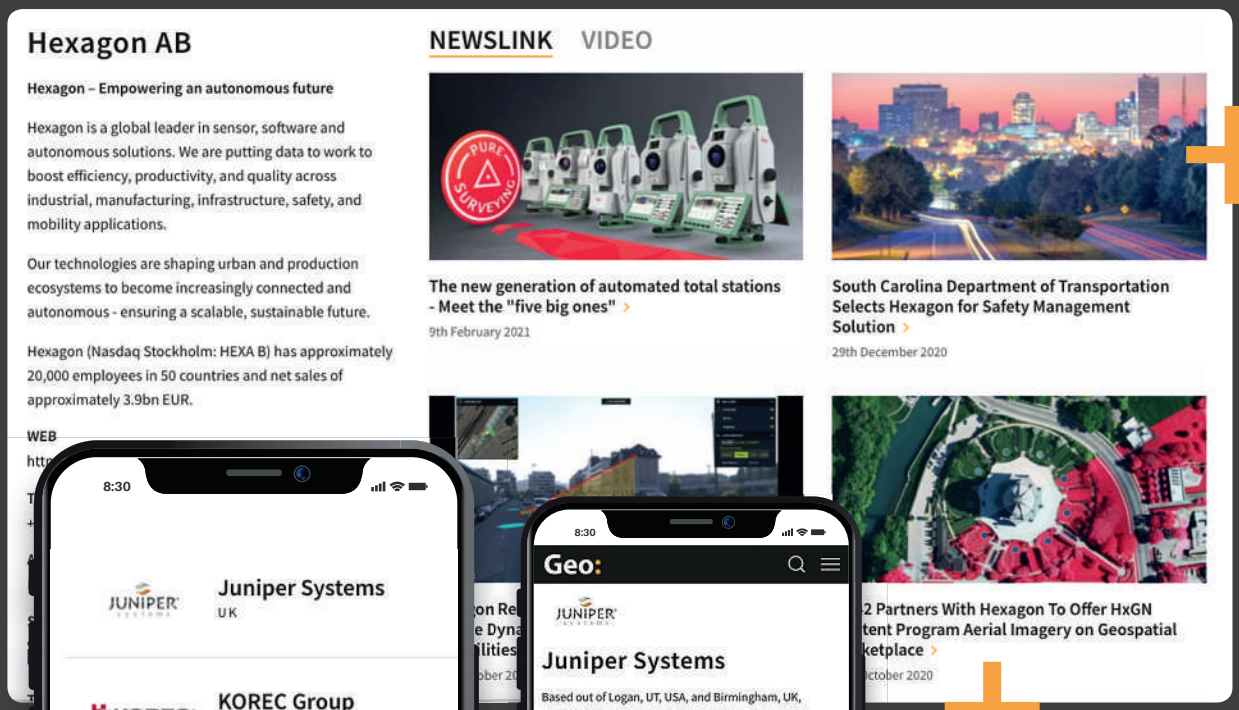

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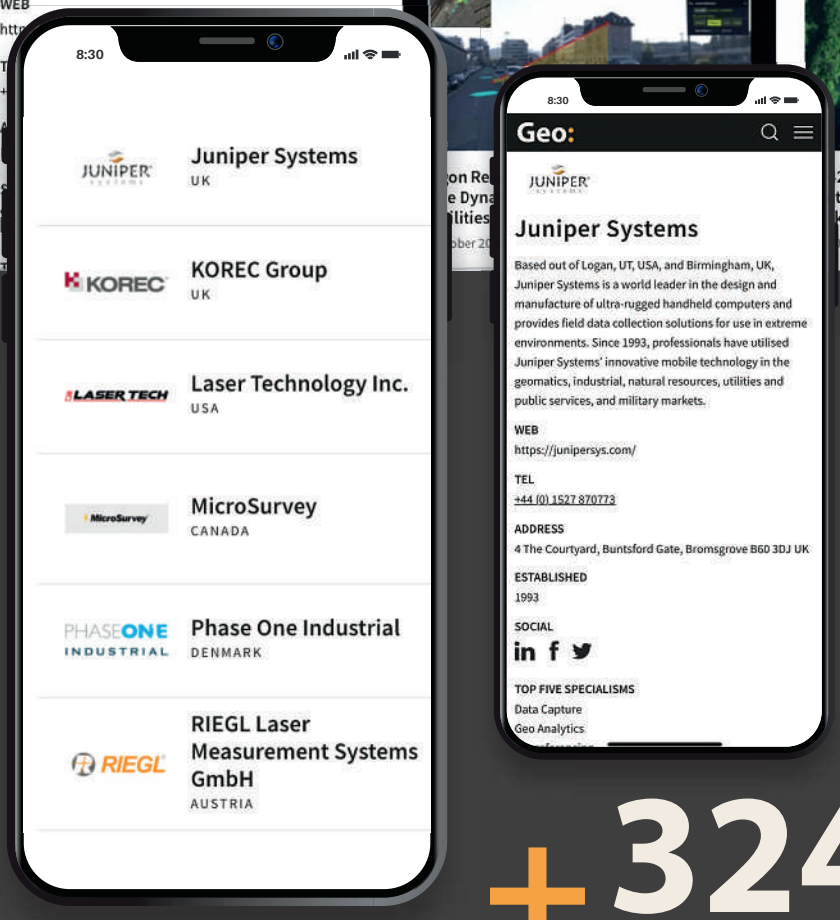

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