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Developing National Earth Observation Capabilities for Australia with Small Satellites

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Abstract

Australia has world-leading capabilities in Earth observation data analytics, applications development, and satellite data calibration and validation. However, until now, Australia has not owned or operated its own Earth observation satellites. The Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia's national science agency, has recently initiated a Space Research Program to develop additional capability in space platforms, focussing on small satellites. Capability will be developed through two complimentary approaches: partnership in an international consortium which owns and operates a sophisticated UK-built small satellite, NovaSAR-1, and Australian design and construction of a lower-cost CubeSat. Furthermore, CSIRO is supporting the development of small satellite technologies for applications including Earth observation across the broader Australian space sector through partnership on the DMTC High Altitude Sensor Systems Program.

In 2017 CSIRO acquired a 10 per cent share of 'tasking and acquisition' time on the NovaSAR-1 S-band Synthetic Aperture Radar satellite. This enables CSIRO to direct the satellite's activity over Australia, download and process data, and make these data available to the wider research community. Following NovaSAR-1's launch on 16 September 2018, CSIRO will commence its own satellite ground operations, and will manage its share of NovaSAR-1 operations as a national research facility.

In mid-2018 CSIRO also commenced a project to acquire its own 3U CubeSat with infrared sensor, in partnership with Australian industry. In addition to providing Earth observation data related to crop health and stress monitoring and vegetation classification, this CubeSat capability will enable research addressing miniaturisation challenges and development of in-flight re-programming methods, automatic detection algorithms, and data correction techniques for rapid on-board data processing that can serve future near-real-time applications. This CubeSat will also provide the opportunity to support Australian companies to gain flight heritage for Australian-manufactured satellite components, and help build Australia's advanced manufacturing capabilities.

Key applications for both S-band SAR and infrared Earth observation data will include agricultural mapping (e.g. crop health and plant biomass) and disaster and hazard monitoring (e.g. floods and fires). Both satellites will give Australian scientists direct control over which data are collected over the Australian region, and enhance Australia's sovereign Earth observation capability.

This paper summarises these initiatives, their technologies and applications, and the national development opportunities arising from them.

Keywords: CSIRO, Australia, NovaSAR, SAR, CubeSat, infrared

Acronyms/Abbreviations

Australia Telescope National Facility (ATNF)
Canberra Deep Space Communication Complex (CDSCC)
Commercial off-the-shelf (COTS)
Commonwealth Scientific and Industrial Research Organisation (CSIRO)
CSIRO Astronomy and Space Science (CASS)
CSIRO Centre for Earth Observation (CCEO)
Defence Materials Technology Centre (DMTC)
Field Programmable Gate Array (FPGA)
High Altitude Sensor Systems (HASS)
International Space Station (ISS)
Surrey Satellite Technology Limited (SSTL)
Synthetic Aperture Radar (SAR)

1. Introduction

Australia has world-leading capabilities in Earth observation data analytics, applications development, and satellite data calibration and validation. However, until now, Australia has not owned or operated its own Earth observation satellites. The Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia's national science agency, has

recently initiated a Space Research Program to develop additional capability in space platforms, focussing on small satellites. Capability will be developed through two complimentary approaches: partnership in an international consortium which owns and operates a sophisticated UK-built micro-satellite, NovaSAR-1, and Australian design and construction of a lower-cost CubeSat. These initiatives are being implemented by the recently established CSIRO Centre for Earth Observation (CCEO).

1.1 CSIRO Astronomy and Space Science

Over the past 75 years CSIRO has built strong capabilities in Earth observation, radio astronomy, space tracking and managing complex facilities. CSIRO currently also applies its expertise in advanced manufacturing, big data management, robotics and cybersecurity to space applications [1].

With the first CSIRO National Space Roadmap and the recently established Australian Space Agency both identifying space-derived services, including Earth observation services, as a national priority (see Section 1.2), CSIRO is seeking to build its capabilities in satellite technology, including satellite operations, sensor specification and on-board data processing.

Much of this space-related activity is being coordinated or supported by the CSIRO Astronomy and Space Science (CASS) Business Unit. On 1 January 2018 CASS established a Space Research Program to encompass much of this work.

CASS hosts two of Australia's national space facilities, the Australia Telescope National Facility (ATNF) and the Canberra Deep Space Communication Complex (CDSCC). The ATNF includes the iconic Parkes radio telescope, the Australia Telescope Compact Array at Narrabri, and the Australian Square Kilometre Array Pathfinder (an array of 36 antennas) in Western Australia. CDSCC is one three stations worldwide that make up NASA's Deep Space Network. CSIRO operates CDSCC on behalf of the Australian Government for NASA.

CSIRO also has world-leading capabilities in Earth observation data analytics, applications development and satellite data calibration and validation. In June 2018 the CSIRO Centre for Earth Observation was formally launched within CASS, under the Space Research Program. The Centre is the first point of contact for engagement with CSIRO on Earth observation science, and it represents CSIRO internationally on Earth observation matters. As well as coordinating a range of Earth-observation-related activities within CSIRO, the Centre oversees several new initiatives to develop capability in relation to small satellite technology [2]. These include:

- a 10% stake in the operational capacity of the NovaSAR-1 satellite
- the acquisition of CSIRO's first CubeSat, and
- partnership on the DMTC High Altitude Sensor Systems Program.

1.2 National Space Priorities

In 2018 the CSIRO Futures advisory group has developed a preliminary national space industry roadmap and guide to key areas of opportunity industry growth. The Roadmap draws on over 200 submissions to the 2017 Australian Government Review of Australia's Space Industry Capability, along with direct consultation with a range of businesses in the Australian space industry and CSIRO subject matter experts in the relevant fields. The Roadmap introduces opportunities for growth in the short- and long term by cross-referencing global trends with Australian comparative advantages and identifies key enabling changes in technology, business and research to help exploit these opportunities.

Three broad opportunity themes were identified for the Australian space industry:

- Space-derived services
- Space object tracking
- Space exploration and utilisation.

The CSIRO Space Roadmap was publicly released in September 2018.

The Australian Space Agency was established on 1 July 2018. With a goal of tripling Australia's space industry by 2030, one of the key priority areas of focus already identified is Earth observation services [3].

2. NovaSAR-1

NovaSAR is a 430kg satellite developed by Surrey Satellite Technology Limited (SSTL), UK. It was launched on 16 September 2018, and is operated by SSTL. It carries both an S-band Synthetic Aperture Radar (SAR) payload with four baseline imaging modes, and an Automatic Identification System payload for ship identification and tracking.

In 2017 CSIRO entered into a partnership agreement with SSTL for access to 10% of NovaSAR-1's operational capacity. This will allow CSIRO to task the satellite and access data over the mission lifetime. Each NovaSAR-1 Mission Partner has an Area of Interest for Priority Access, which in CSIRO's case is Australia's Exclusive Economic Zone. CSIRO can also request the acquisition of data elsewhere around the world, and can download data directly to an Australian receiving station. CSIRO is licensed to use and share the data for its own research purposes, and those of its partners and collaborators.

A key advantage of the SAR imager is that it enables day/night and all-weather imaging. With a

revisit rate of 14 days, applications of the data may include disaster impact assessment (e.g. following cyclones) and collection of time series data for regular monitoring of variables such as tropical crop growth, urban development or land use change.

Australian access to NovaSAR-1 will be operated as a national facility, with requests for data acquisition to be managed via a process similar to the way in which access to the ATNF facilities is managed.

3. CSIROSat-1 CubeSat

In 2018 CSIRO secured funding to acquire a 3U CubeSat, 'CSIROSat-1', which is to be built and launched within 2 years. Its key purpose is to enable new science and research using equipment not currently available to CSIRO.

The CubeSat is currently in the preliminary design phase. However, it will carry a commercial off-the-shelf (COTS) shortwave infrared imager with bandpass filter and a COTS Field Programmable Gate Array (FPGA) on-board data processor. The key target applications will be related to crop health and stress monitoring and vegetation classification.

This acquisition is a collaborative effort between CSIRO, Australian industry and partner research organisations. While CSIRO will provide sensor system requirements and data processing software, Australian space start-up company Inovor Technologies Pty Ltd will design, build and integrate the satellite. CSIRO is also receiving support from collaborating research organisations including the University of New South Wales, the Australian National University, and the Defence Science and Technology Group on mission design, testing and commissioning, as well as support from industry on applications development.

4. DMTC High Altitude Sensor Systems Program

As outlined in Section 1.2, Earth observation services have been identified in 2018 as an Australian industry priority by both CSIRO and the Australian Space Agency. However, the 2016 Defence White Paper also highlighted the importance of ensuring the security of Australia's space-enabled capabilities, and prioritised strengthening Defence space surveillance and situational awareness capabilities. Significantly, in June 2017, the Australian Geospatial Intelligence Organisation announced DEF799, a $500 million investment to improve Australia's space-based intelligence, surveillance and reconnaissance (ISR) capabilities. While the first phase of this program focuses on improved access to commercial satellite imagery, the second phase may include possible acquisition of a sovereign space surveillance system.

DMTC is a not-for-profit collaborative technology project management company, of which CSIRO is a partner [4]. DMTC focuses on developing domestic technologies that will enable Australian industry to provide new or more effective capability to the Australian Defence Force or in the national security context. Recent developments in Australian space-related priorities, coupled with the increasing accessibility of small satellite platforms, led CSIRO and DMTC to identify a new area of emerging opportunity for Australian industry: the development of enhanced sensor components and on-board data processing for CubeSats and/or small unmanned aerial systems with a payload capacity of up to 5kg. This led to the establishment of the DMTC High Altitude Sensor Systems (HASS) Program in 2017.

Four projects have been initiated to date under the HASS Program, with a fifth project currently under development. These projects include:

- Development of a prototype GPS reflectometry sensor payload for deployment on unmanned aerial systems
- Development of a compact visible/near-infrared hyperspectral imaging system (including a near-real-time on-board data processing system) that can be accurately pointed at large off-nadir angles and is suitable for flight on a small unmanned aerial system
- Manufacture of CubeSat components (and in particular an optical bench) from low- or zero-thermal-expansion alloys such as Invar, using advanced 3D printing and casting methods
- A feasibility study of the development of compact high-performance cryogenic Ka-band and THz receivers for potential application in airborne/spaceborne sensing and communications
- Opto-mechanical design of a CubeSat-deployable hyperspectral imager for the coastal ocean.

These projects are all expected to be completed by end 2020.

5. Summary

In 2017 and 2018 CSIRO has expanded its space-related activities to include several new initiatives focusing on the development of small satellite capabilities with Earth observation applications.

The purpose of these initiatives is twofold: to enable CSIRO to develop the capabilities needed to design, operate and utilise data from more complex space-based imaging systems for Earth observation applications in the future, and to foster the development of globally competitive Australian industry capabilities.

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