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Unlocking Innovation: Satellite Technology's Practical Applications in Transport Infrastructure

roads australia

Executive Summary:

The question at the forefront of the 2023 Roads Australia Fellowship cohort is how to address the pressing labour shortage and productivity challenges within the transportation industry. Our team contends that the solution lies in both tapping into new resource streams and harnessing the power of technological innovation to achieve more with less. This report explores the transformative potential of the rapidly expanding space industry and how it can revolutionize our approach to road asset management and infrastructure.

The challenge that was given the 2023 Roads Australia fellowship cohort was to research a technical innovation that could alleviate the pressures on a constrained workforce while also attracting new streams of talent to join the industry. Following on from what was defined in our initial approach within the scoping paper we engaged with a number of parties to both understand satellite technology and the applications within the roads and infrastructure industry.

Satellite data is more than just imagery, with a variety of sensors able to measure a broad spectrum of information to build a complete dataset. The use of Synthetic Aperture Radar (SAR) has grown rapidly over the past 2 decades as the technology has both become more readily available and cost effective. Data is now readily accessible and the key to unlocking it potential in a broad range of applications is the computation algorithms.

Fundamental to the project is how the technological innovation can supplement or replace roles in the industry to free resources to help elsewhere in the industry. Our research showed that satellite technology can reduce the hours required for labour intensive asset management tasks, as well as reducing the need for remote and potentially hazardous work. Additionally, the space and data analytics field that would be introduced to our industry, could provide a channel for new and diverse streams of talent.

The research that we undertook showed that the use of satellite data and information to support the road asset management has real potential with the technology and processing systems already in place. Our research suggests that there is nothing preventing this application initially on rural road assets to develop and calibrate the technology before more widespread adoption. Satellite monitoring could significantly alleviate pressure on the workforce and reduce the need for remote working.

The key next steps are to build general awareness of the potential and application across the industry, while developing a framework and governance structure to control the technological development.

Figure - Satellites have a real role to play in innovating our industry

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1 Introduction and Project Context

1.1 Background

The infrastructure and construction industry stands at a crossroads in 2023, grappling with a confluence of challenges that demand innovative solutions. Chief among these challenges is the pressing issue of a labour shortage and the need to boost productivity within the infrastructure and transport construction sector.

The challenge that the RA fellowship program has given to the 2023 cohort:

> *What is one* ***technical innovation*** *that we can introduce to our industry that will help us achieve RA policy objectives and open up opportunities for* ***new streams of talent*** *in our workforce.*

There are two key elements from this challenge statement that we have endeavoured to address as part of this project:

> **TECHNOLOGICAL INNOVATION** – How can we utilise technology to improve productivity by supplementing or replacing tasks roles currently delivered by the constrained labour market?

> **NEW STREAMS OF TALENT** – What new streams of talent could enter our industry as a result of the new technology?

Our team believes the answer is both in new resource streams and talent paired technological revolution to deliver more with less. To achieve this, we believe that the rapidly growing space industry can significantly innovate our approach to road asset management and infrastructure.

As demands on transportation infrastructure grow, budget constraints tighten, and experienced personnel within road agencies become scarcer, it is imperative to seek novel approaches to address these critical issues.

1.1.1 Labour Shortages in the Australian Context

In recent years, the Australian labour market has faced significant challenges related to the availability and retention of skilled workers in the infrastructure and transportation sectors (Australian Government, 2021). The nation's aging workforce, combined with a lack of succession planning, has resulted in a widening gap in skilled labour (Hajkowicz et al., 2019). Additionally, the cyclical nature of

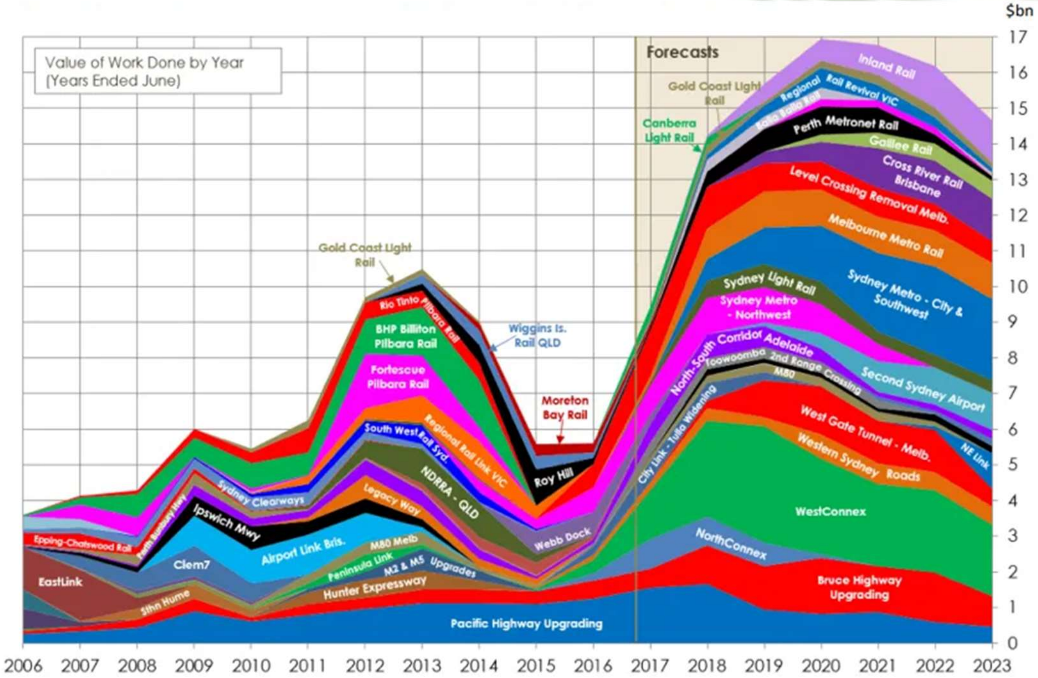

Figure 1 - Australian Annual Infrastructure expenditure 2006-2023 ($B) source Macromonitor

infrastructure projects often leads to fluctuations in demand for labour, making it challenging to maintain a stable workforce (Infrastructure Australia, 2019).

The impact of labour shortages on infrastructure projects is profound. Delays, cost overruns, and compromised project quality are common consequences (Infrastructure Australia, 2019). Furthermore, the competition for available skilled labour can drive up wage costs, putting additional pressure on project budgets (BIS Oxford Economics, 2019).

This labour shortage has been exacerbated with the growth in Infrastructure spending and the rise of "mega projects' across Australia. Between 2006 and 2023 there has been a fourfold growth in infrastructure expenditure from $4B to over $16B. This growth in expenditure has far exceeded the growth in the labour resource pull in the sector at the same time that productivity has effectively decreased.

1.1.2 Productivity Challenges in Transport Infrastructure and Construction

Productivity challenges within the Australian transport sector are multifaceted. These challenges include inadequate utilisation of existing infrastructure, congestion, and inefficiencies in maintenance practices (Department of Infrastructure, Transport, Regional Development and Communications, 2020). The "productivity gap" is a critical concern, with productivity growth in the transport sector lagging behind other industries (Bartels et al., 2018).

Australia's infrastructure construction sector faces critical productivity hurdles, most notably a widespread labour shortage. This deficit, spanning both skilled and unskilled workers, results from a combination of factors including an aging workforce and a dearth of new entrants with requisite skills. Intensifying the challenge, the industry competes fiercely with other sectors for available talent.

Adding to this complexity is the persistent issue of skill mismatch. Workers often find themselves ill-equipped for the specific demands of infrastructure projects, leading to inefficiencies in execution. This underscores the urgent need for targeted training and upskilling initiatives within the sector.

Navigating the stringent regulatory framework presents another formidable obstacle. Complex and demanding regulations governing construction projects can hinder progress. Obtaining necessary permits and adhering to compliance standards can be time-consuming and costly. Striking a balance between regulatory compliance and swift project execution remains a delicate task.

While technology has revolutionized many industries, the infrastructure construction sector in Australia has been slower to adopt modern construction technologies. Innovations like Building Information Modelling (BIM), drones, and advanced project management software hold significant potential for productivity gains, highlighting the urgency for technological advancement.

The industry contends with a fragmented supply chain, leading to coordination challenges and delays. Streamlining the supply chain, enhancing communication, and implementing robust inventory management practices are crucial steps to alleviate these bottlenecks.

Project complexity continues to rise, demanding a comprehensive approach integrating various systems, stringent environmental considerations, and adherence to evolving sustainability standards. These requirements necessitate heightened project management expertise, often resulting in prolonged timelines and increased costs.

Addressing these challenges requires investment in comprehensive training programs, technology adoption, streamlined regulatory processes, and a culture of collaboration and innovation across the supply chain. Additionally, efforts to attract and retain a diverse pool of skilled workers will be pivotal for the long-term sustainability and productivity of the Australian infrastructure construction sector.

1.2 Scope of the Report

This report delves into the multifaceted dimensions of addressing the labour shortage and productivity challenges within the transport sector. Our team contends that the solution lies in both tapping into new resource streams and harnessing the power of technological innovation to achieve more with less.

This report explores the transformative potential of the rapidly expanding space industry and how its practical application can be used in existing and future construction of transport infrastructure.

The report encompasses an analysis of the current state of labour shortages and productivity constraints, an exploration of the role of satellite infrastructure and imagery, and an examination of the integration of space industry innovations into road asset management. Furthermore, the report considers strategies for diversifying resource streams and nurturing new talent while embracing technological revolution as a means to optimise productivity.

Noting the feedback from received from the Road Australia Future Leaders Committee and the breadth of the topic and future technological development, the SA/WA group are focusing on key areas that we feel would provide the most benefit in the short to medium term.

The challenge given to the 2023 RA fellowship cohort is a hugely complex, and one in which there is no ‘silver bullet’ or single solution to resolve. Instead, our industry will need a broad range of solutions from attracting more talent, driving innovation, policy changes as well as adopting technological developments. Therefore, we have specifically focused on a single area where we can focus this innovation to address the labour challenges facing our industry. Our focus area is the maintenance of rural roads as a starting point to test the technological innovation with the view it could be expanded to the whole road network in the future.

1.3 Deviation from Scoping Paper

The approach and the methodology generally followed what was outlined within our scoping paper, which had a strong focus on engaging with stakeholders to understand the potentially opportunities and feasibility of using satellites within the road industry. However, following the feedback we received on the scoping paper we made two changes to our project;

Limiting the scope – We took onboard feedback that we might be trying to take on too much, so we refocused the scope to be more specific with a smaller pool of key stakeholders.

Consideration of AI and Machine Learning – We took onboard the feedback to consider the role that artificial intelligence and machine learning could play in the roll out of satellites within the roads industry

During our research we learnt that our proposed innovation was much closer to reality than we initially thought, therefore we focused on how the existing technology and data available can we be utilised in our industry and practical ways this can drive efficiency.

1.4 Alignment with Roads Australia Policy

Roads Australia has made deliberate decisions to focus its strategic policy around 5 streams to focus its industry advocacy and development including.

- Capacity
- Customer Service
- Safety
- Sustainability
- Transport reform

This research assignment has been chosen and shaped in order to align with Roads Australia's policy objectives and the conclusions that we have drawn directly support RA's strategic goals. Further details on the alignment to RA's policy streams can be found in section 4.3 below.

2 Project Approach

The findings presented in this report are the result of a comprehensive research methodology. Primary research sources include interviews with experts in the field of Infrastructure maintenance, satellite technology, the broader space industry and road asset management.

Additionally, we conducted surveys and analysed case studies to gain insights into real-world applications. Secondary research involved an extensive review of existing literature, reports, and academic studies related to transportation, satellite technology, and labour challenges in the industry.

The synthesis of primary and secondary research forms the foundation of our analysis and recommendations. This methodological approach ensures that the insights and proposals presented in this report are grounded in empirical evidence and informed by best practices from both the public and private sectors.

In order to provide a structured approach to our research project, we provided a four-stage process that we have followed to understand and shape our response to the research project.

Table 1 - Summary of Approach to Research Project

Discover	Define	Develop	Document
Literature Review: Problem Definition: Concept/Approach Definition:	Interviews/Information Gathering: Benefits Based on Authority Feedback: Constraints and Authorities' Perspectives: Authorities' Application and Implementation Strategies:	Implementation of Satellite-Based Infrastructure Monitoring: Roadmap for Implementation: Introduction of New Workforce Inc Opportunities: Predicting Benefits:	Document Impact Assessment Report: Talent and Labour Optimisation Analysis: Case Studies and Success Stories: Future Opportunities

2.1 Stakeholder Engagement

In order to better understand both the problem and solution a key component of our research was to engage with key stakeholders to gain insights into what might be possible and how satellites can contribute to Roads and Infrastructure sectors in the future. To gain a broad view we targeted stakeholder in 3 distinct categories

- Satellite Technology – Understand the technology and its potential application
- Road Authorities – Understand current state of road asset management and challenges from an asset owner perspective
- Maintenance Contractor – Construction Partner delivering asset maintenance for Road Authorities

Table 2 - Summary of Key Stakeholders engaged during research

Stakeholder	Stakeholder	Reason for engaging
Satellite Technology	Australian Space Agency	Following its establishment in 2018, the ASA has coordinated the growth of the civil space industry in Australia. The ASA is a non-statutory entity in the Department of Industry, Science and Resources.
	D-CAT	D-CAT provides data analytics specialising in providing intelligence from the high-quality data and image sources obtained from satellites, drones or IoT devices.
Road Authority	DIT	Departure of Infrastructure and Transport. South Australian Government body tasked with delivering and maintaining transport infrastructure. Being the employer of a member of the Project Group, we would seek detailed insight into the maintenance requirements across the metro and rural areas.
Road Maintenance Contractor	DM Roads	DM Roads is Downer's road network management and maintenance business. DM Roads work in NSW, VIC, SA, WA

3 The Innovation Findings

Satellite infrastructure is obviously not a new innovation, with the first full scale satellites being first proposed in 1945 and tested in the 1950's. This was followed quickly by the first weather satellite launched by the USA in 1960, which transmitted infrared images of cloud cover for the purpose of tracking weather, and specifically hurricanes. The following 60 years has seen significant growth in satellite usage to where it now constitutes a critical component of the technological ecosystem that underpins modern society.

Simply being able to transmit using radio waves from orbiting satellites to Earth opened the technology up to a myriad of purposes, from global communication to navigation and Earth observation. Despite the broadness of the application and continued growth that has occurred, the civil and infrastructure sector still appears to be "late to the party".

This is evident with one type of active satellite mounted sensor in particular, Synthetic Aperture Radar (SAR), which is already operating across the primary industries of agriculture, mining & the energy sectors from large scale crop & gas pipe monitoring, site selection to vegetation growth and emergency response. It is however, yet to be adopted at scale by the roads and transport sectors.

Through this section of the paper, we will explore the value of SAR, the recent growth in SAR research in transportation and infrastructure sectors, and its practical applications.

3.1 The Value of Synthetic Aperture Radar (SAR) Imagery

In the ever-changing landscape of Earth observation technology, SAR has emerged as a powerful tool to provide unique and invaluable insights into our planet through the ability to observe through adverse conditions.

Originally designed for military use during the Cold War, SAR technology has since evolved into civilian applications, changing the way we see and interact with the Earth's surface. Where conventional optical imaging satellites rely on visible light,, they are subsequently hampered by clouds, fog, or lack of daylight, rendering them useless at night or in bad weather. SAR however, operates in the microwave region of the electromagnetic spectrum. SAR emits its own microwave signal, which bounces off the Earth's surface and comes back as a sound wave which is the analyses and processed into images, making SAR ideal for all-weather, day and night monitoring.

This fundamental difference gives SAR a unique capability that cannot be accomplished with other Earth observation techniques.

This application is now entering a new stage where is has the potential optimise and enhance the maintenance management of a variety of infrastructure by combining the macro data acquired by SAR with the micro data collected on the ground.

It delivers exceptionally high-quality imaging, revealing incredible detail that other imaging technologies may miss. The radar pulses transmitted by SAR sensors can be manipulated to obtain different patterns, allowing them to detect details such as individual buildings, trees, or even changes in soil moisture.

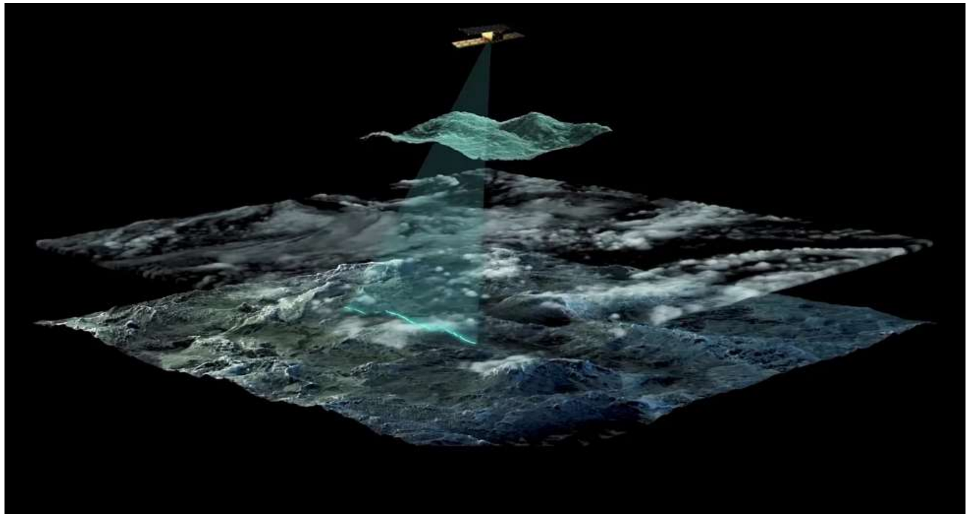

Figure 2 - Artists impression of SAR

SAR possesses the remarkable ability to detect even the slightest ground movements with submillimeter accuracy. This capability in geohazard monitoring, such as tracking tectonic plate shifts, volcanic activity, or ground subsidence in urban areas. With SAR's sensitivity to deformation allows for early warning systems, providing vital information for disaster preparedness and response.

An inherent value that satellite data has is the availability of authentic information about Earth's surface, weather, and other incidents. Cumulative data helps to understand developments in long-term and timely data to act swiftly on the detected issues. The number of satellite data applications is unlimited, providing manyfold advantages on global and local scale.

The diagram below from NEC explains the microwave process very well, with differing band lengths having the ability to pick up and generate images using microwaves transmitted and reflected off objects on the surface of the earth. Band length X for example reflects up tree foliage, Band L goes through foliage and branches and reflects off tree trucks and the ground. The differing microwave bands are used to provide an image.

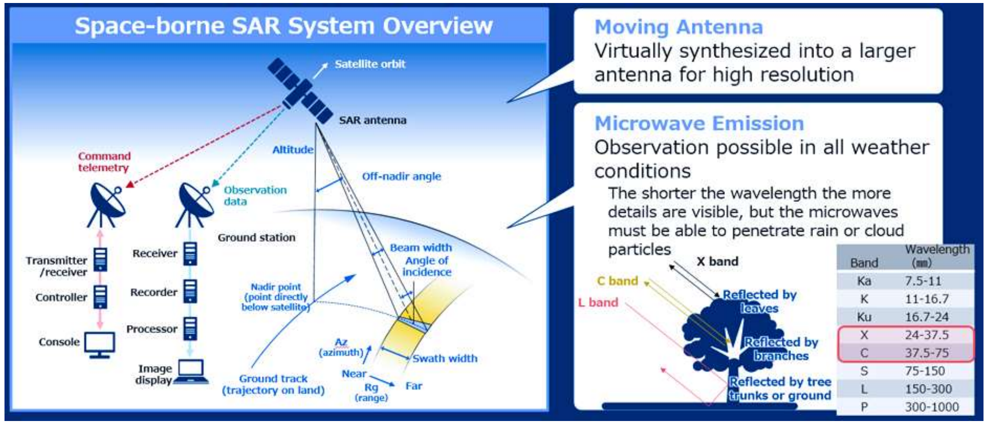

Figure 3 NEC Infrastructure Maintenance Management Using SAR Satellite

The value and interest of Synthetic Aperture Radar (SAR) Imagery in infrastructure is growing, in a recent a paper published by MDPI (Jan 2023) the authors compiled and reviewed research publications from the Scorpus scientific database. The trend illustrated below shows that research papers in this field are increasing. This is also evident through talking to DCAT and DIT who are undertaking Pilot projects in relation Infrastructure monitoring, which an overview will be provided in section 3.4 of this paper.

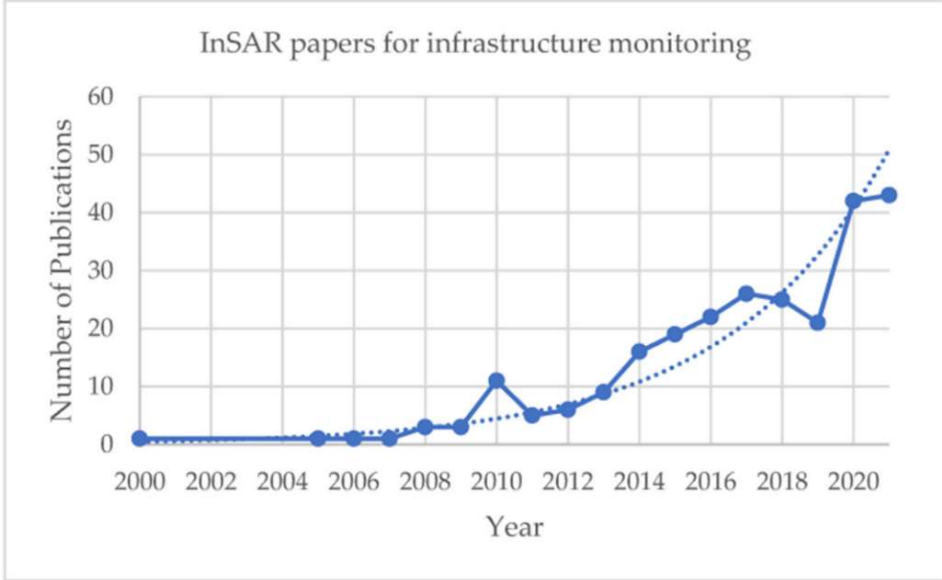

Figure 4 Chart showing growth in SAR research papers

3.2 Current Challenges of Australian Road Authorities

Australia's extensive road network is the lifeblood of its economy, connecting cities, towns, and regions across vast distances. As demands on this critical infrastructure continue to grow, road authorities face a complex web of challenges.

The challenges confronting road authorities are multifaceted and dynamic. They include budget constraints, scarcity of experienced personnel within their agencies and industry and the constant pressure to meet evolving policy objectives, including safety, sustainability, and efficiency. Moreover, as the transportation demands on their networks increase, road authorities must find ways to optimise resource allocation and enhance their ability to respond swiftly to unforeseen events. Challenges faced by Australian Road Authorities include;

- *Aging Infrastructure:* Many roads and bridges are aging and in need of repair or replacement, leading to increased maintenance requirements and costs.
- *Budget Constraints:* Limited funding for maintenance and infrastructure upgrades can hinder the ability to address maintenance needs adequately.

- *Workforce Shortages:* The road maintenance industry is facing a shortage of skilled labour, making it challenging to find qualified personnel to perform maintenance tasks.
- *Climate Change:* Extreme weather events, such as heavy rainfall, flooding, and heatwaves, can accelerate road deterioration and increase maintenance needs.
- *Traffic Growth:* Increasing traffic volumes can lead to faster road wear and tear, requiring more frequent maintenance.
- *Data Availability:* Access to real-time data on road conditions and asset performance is often limited, making it challenging to prioritise maintenance efforts effectively.
- *Sustainability:* Balancing maintenance needs with environmental sustainability goals, such as reducing carbon emissions, can be a challenge.
- *Regulatory Compliance:* Meeting regulatory requirements for road safety and environmental impact can add complexity to maintenance planning and execution.
- *Asset Tracking*: Keeping track of the condition and performance of road assets, such as signs, signals, and pavement, can be challenging without advanced asset management systems.
- *Public Expectations:* Meeting public expectations for well-maintained roads and infrastructure while managing limited resources can be a balancing act.
- *Technological Adoption:* Embracing and implementing new technologies, such as remote sensing and predictive maintenance tools, can be a challenge for some agencies.
- *Emergency Response:* Rapid response to unexpected events, such as accidents, landslides, or natural disasters, can strain maintenance resources and disrupt regular schedules.

Amidst these challenges, road authorities need not only effective solutions but also a vision for the future. They require innovative approaches that enable them to do more with fewer resources, align their operations with their policy objectives, and bridge the skills gap in their workforce. Ultimately, they seek tools and practices that can help them enhance the sustainability and resilience of their infrastructure.

Figure 5 - Sturt Highway Damage - Picture: Spuds Roadhouse

3.3 Practical Applications of SAR the Transport Industry

The following breaks down the contributions of satellite technology within the context of the two pillars, asset management and maintenance scheduling, which in turn will lead to the labour use optimisation required to meet current demands.

3.3.1 Asset Management

Within the sealed and unsealed networks across Australia, regular safety inspections are undertaken. This frequent task is currently undertaken by people in vehicles, collecting defect and asset condition data, with the overall frequencies of these inspections varying from State to State and differing depending on the classification of road.

Driving this network is expensive, time consuming, poses significant health and safety considerations in additional to generating a considerable Co2 footprint.

Further to this, the unsealed network of Australia is either in rural or extremely remote areas, making assessing road conditions difficult to assess simply due to their remoteness.   Road Condition Modelling, Deterioration models, Situational data is not readily available when it is needed or takes a long time to capture leading to possible poor decision making. Situational data and awareness is critical and inherently intertwined with effective planning, with enhanced situational awareness resulting in more informed planning and better post-extreme weather event response.

Satellite data for Asset Management

SAR technology, if combined with highly competent data analysts can provide;

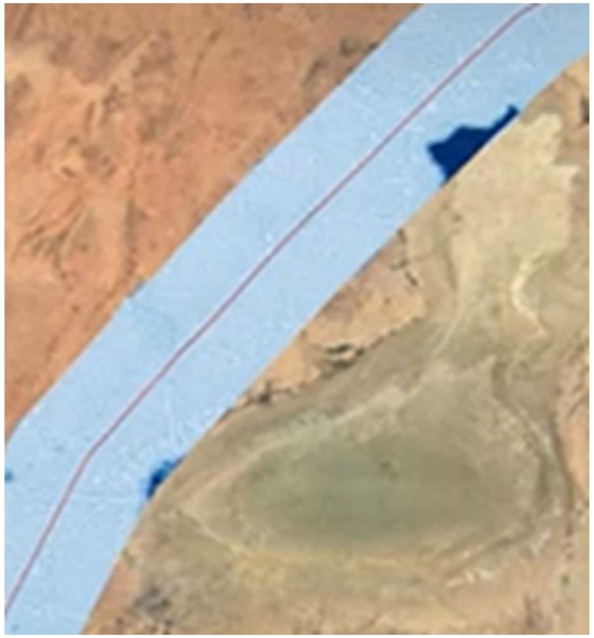

Figure 6 Unsealed Road Moisture Map Example - DCAT

- *Detection of Structural Changes:* SAR data can detect and monitor changes in infrastructure assets over time, such as deformation, subsidence, or shifts in infrastructure alignments. This helps identify potential structural issues and supports maintenance planning and asset management.
- *Assessment of Infrastructure Health:* SAR data can be used to evaluate the health and condition of infrastructure assets. It can identify cracks, deformations, roughness calculations or other signs of deterioration, enabling timely maintenance interventions and ensuring the safety and reliability of infrastructure systems.
- *Flood Monitoring*: In remote regions, SAR technology can be used due to its all-weather, day-night capabilities, and accurate flood boundary delineation. It also has the ability to provide regular data capture in a way that was not previously possible. It also overcomes the difficulty in acquiring precise catchment elevation data, establishing the intricate dynamics between floodplains and channels, and the general logistical hardships of obtaining flow and depth data in remote locations.

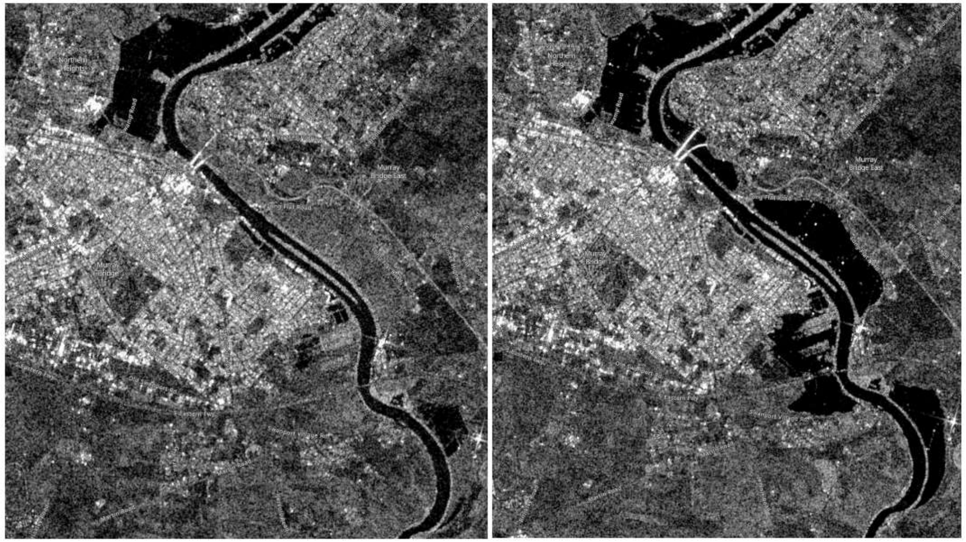

Figure 7 SAR Imagery of Murray River Flooding. Jan 2023 – Sentinel Hub – Sentinel 1 Satellite

- *Vegetation Encroachment Detection:* SAR can identify vegetation encroachment on infrastructure, such as roadsides, power lines, or railway tracks. This assists in vegetation management and prevents potential hazards, such as falling trees or hindrance to transportation infrastructure.
- *Mapping and Planning:* SAR data can support infrastructure mapping and planning, including the identification of suitable locations for infrastructure development, route optimization, and land use planning. It provides valuable information on topography, land cover, and surface characteristics.

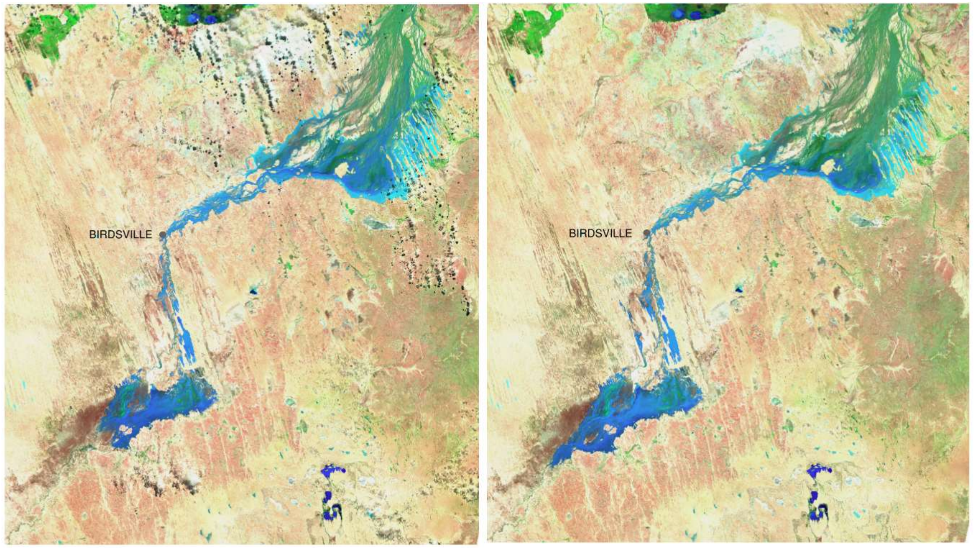

Figure 8 Satellite Map adjacent Birdsville, showing flood progression and subsequent vegetation health through moisture assessment, June 2022 – Sentinel Hub - Sentinel 2 Satellite

- *Data Acquisition:* allowing for efficient data collection over large areas, including remote and inaccessible locations.
- *Data Analysis:* Advancements in analytics can extract meaningful insights from satellite information,
- *Monitoring of Ground Stability:* SAR can assess ground stability, including soil moisture content, subsurface movement, and slope stability. This information is crucial for monitoring infrastructure in areas prone to landslides, sinkholes, or other geotechnical hazards.

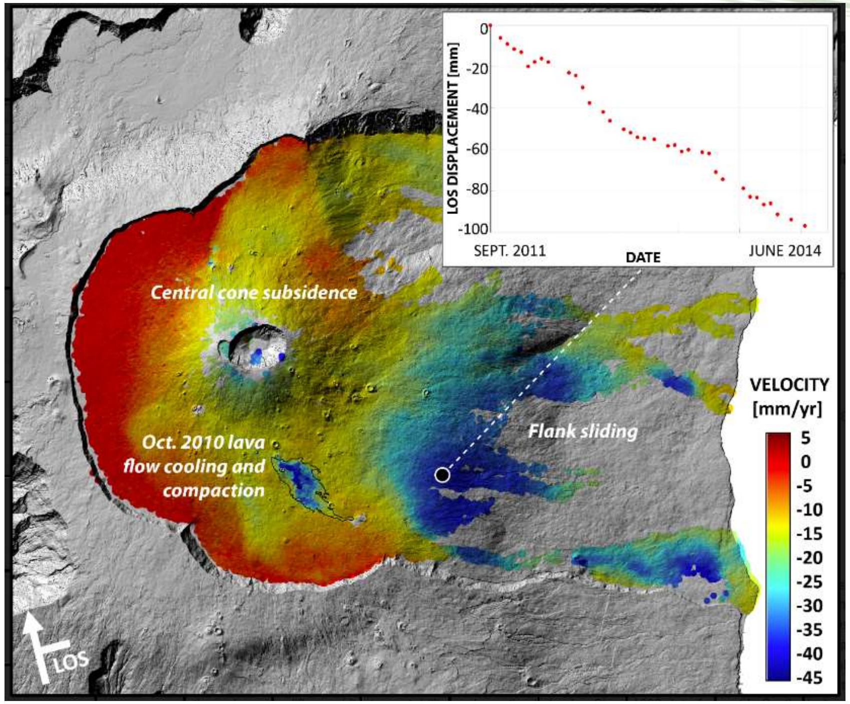

Figure 9 3-year Line of Sight Displacement Velocity and Lava Flow Subsidence

- *Predictive Capabilities:* By leveraging historical and real-time data, satellite technology enables predictive maintenance, reducing costs and downtime.
- *Efficient Resource Allocation:* Authorities can allocate labour and resources more efficiently, optimising their workforce and improving safety.
- *Emergency Management:* Improved resilience and response capabilities, the workforce can better protect communities and restore normalcy faster. Prioritising critical repairs, minimising disruptions.
- *Environmental Impacts:* Satellite technology can also play a crucial role in assessing the environmental impact of existing road infrastructure, as well a new major road and transport projects. An example being the assessment of erosion and sedimentation for during and after any major earthworks project, with SAR data being able to reveal changes in sediment transport patterns, sediment deposition in rivers or reservoirs, and the extent of erosion in construction zones.

Further research by Esri Australia looked into SAR imagery for road maintenance in particular subsidence of roads in the Brisbane area. Over the two-year period the team analysed a road corridor near Brisbane Airport which showed deformation had occurred at levels up to 30mm per year.

Satellite technology exhibits exceptional efficiency in covering vast geographical areas, a capability that proves particularly valuable for overseeing extensive road networks. This efficiency empowers authorities to concurrently monitor the condition of multiple assets, optimizing infrastructure management practices.

Notably, the WA/SA team was apprised of the Department for Infrastructure & Transport in South Australia's pursuit of two pilot Proof of Concept projects centred on SAR data.

> ***DIT Project – Proof of Concept**: This project is dedicated to the Satellite-Based Pavement Condition Monitoring of the Department for Infrastructure & Transport's (DIT) sealed road network.*
>
> *Key Project objectives:*
>
> *Establishing the accuracy of estimated International Roughness Index (IRI) against measured IRI, at both 100-meter and 10-meter segment levels.*
>
> *Establishing the accuracy of estimated Pavement Health Index (PHI) against calculated PHI, also at the 100-meter and 10-meter segment levels.* Calculating condition changes to enable the modelling of unique predictive deterioration curves.

Furthermore, during discussions with DM Roads, the company highlighted its exposure to SAR data, particularly in the context of pavement deterioration following extreme heat events in the Victorian high country. In this application, satellite data is employed to monitor pavement temperature over time while also identifying signs of roughness and subsidence. DM Roads also mentioned SAR's broader use within the Downer Group, where Machine Learning and AI applications are explored, particularly in the defence sector.

3.3.2 Maintenance Scheduling

Data Driven Decision Making

Satellite imagery and data analytics have the ability to enable data-driven decision making for maintenance scheduling. By analysing imagery and associated data, authorities can identify areas in need of immediate attention and prioritise maintenance activities accordingly.

A perfect example of this is for the regrading of remote Australian outback roads. A significant amount of the cost in rural unsealed road regrading is in the need to cart water to these extremely remote locations to achieve the optimal moisture content for grading.

> ***DIT Project – Initial Feasibility**: This initiative focuses on South Australia's extensive unsealed road network, spanning approximately 9,000 kilometres. Its primary objectives include:*
>
> *Monitoring surface water movement across roads during flood events.*
>
> *Understanding optimal moisture conditions for effective grading.*

SAR sensors rely on the interaction between radar waves and the road surface, which can therefore be used to assess moisture content in roads and other surfaces. This could then easily lead to maintenance scheduling where grading is deployed at times where the need to cart water potentially hundreds of kilometres is avoided.

In addition to this, using historical data and near real time monitoring of road infrastructure, including or road deformation levels, pavement condition, floodway conditions, it will allow for maintenance activities to be planning based on actual conditions, e.g Small Culvert Replacements when creek inverts are dry.

Predictive Maintenance

The logical next step following the use the above data is to take historical maintenance scheduling and combine with a consistent feed of satellite obtained data to develop machine learning algorithms which would then look to predict when and where road maintenance may be required. These algorithms over time, will more and more accurately predict where asset failures may occur by considering a multitude of factors. These could include the asset type, the asset age, usage patterns, environmental conditions, and real-time monitoring data.

This AI-driven predictive maintenance model can then ensure that maintenance activities are performed when they have the least impact on road users by factoring in variables like traffic patterns, weather forecasts, and crew availability.

Emergency Response

In the event of natural disasters or unexpected asset damage, even more simplified satellite imagery can rapidly assess the situation, helping authorities deploy maintenance crews and resources to critical areas promptly.

Particularly in remote areas, where flood extents and damage are extremely difficult to quantify, the ability to immediately and accurately determine the extent of pavement damage, road closes, culvert breakouts or erosion that has occurred would be extremely valuable. The assistance could be as simple as determining the size of the excavator to transport out to a floodway on the Outback Highway, or the amount of traffic signage needed to close the Sturt Highway following flood damage, but it is potentially in this simple assistance in decision making where where the value lies.

On September 6th , 2023, the Federal Government announced the selection of ICEYE, a world-leading provider of natural catastrophe solutions and insights who operate their own constellation of SAR satellites for Near Real-Time Flood and Bushfire Data to Strengthen Disaster Response.

The Government had been using ICEYE's Flood Insights product since October 2022 to support response and recovery activities across more than 30 agencies at both state and federal level. During the period, ICEYE analysed eight major floods, enabling a more targeted response effort, reducing related costs, and facilitating quicker disaster relief assistance to affected communities during one of the most catastrophic flood hazard seasons in recent history.

Australia is playing a leading role in global efforts for the provision of operational standardised Earth Observation datasets (i.e., Analysis Ready Data), including through Open Data Cube initiatives such as Digital Earth Australia (DEA) http://www.ga.gov.au/dea. With the inclusion of SAR data via ICEYE, more will be known about how this data will apply in the Australian context and how they could aid in national hazard identification and monitoring.

While addressing the key benefits associated with the implementation of SAR technology in road asset management is crucial, it's equally vital to explore avenues that can further amplify the benefits of this transformative innovation. One such avenue lies in the integration of Artificial Intelligence (AI) and Machine Learning (ML) techniques into the SAR data ecosystem.

Integration of AI and Machine Learning

A common theme throughout this innovation is the continuing advancement in the integration of AI and ML algorithms into data analysis and predictive maintenance workflows. AI & ML excel in extracting meaningful insights from large and complex datasets, which is precisely what satellite imagery and sensor data represent. By incorporating these advanced technologies, it has the possibility to bring about several transformative benefits;

- **Predictive Maintenance**: As noted previously, AI and ML algorithms can analyse historical SAR data, weather patterns, and asset condition & defect data to predict when road assets (such as pavement or bridges) are likely to require maintenance or repairs.
- **Resource Optimisation:** By analysing SAR data in real-time, AI could optimise the allocation of maintenance crews, equipment, and materials. This ensures that resources are deployed efficiently, reducing operational costs and minimising disruptions to road users.
- **Data Analysis:** SAR generates vast datasets that can be overwhelming to analyse manually. ML algorithms can process this data quickly and accurately, extracting valuable insights about road conditions, traffic patterns, and environmental factors.
- **Risk Assessment:** AI-driven risk assessment models can identify areas of the road network that are prone to specific hazards, such as flooding or landslides. This enables road authorities to implement targeted mitigation measures and enhance overall road network resilience.
- **Emergency Response:** ML algorithms can analyse SAR data in real-time to detect and assess the impact of natural disasters or extreme weather events on road infrastructure. This information aids in swift emergency response coordination and resource allocation.
- **Environmental Sustainability:** AI can help road authorities reduce the environmental footprint of maintenance activities. By optimizing routes and schedules, it minimises fuel consumption and emissions from maintenance vehicles.
- **Decision Support:** AI-powered decision support systems provide road authorities with actionable insights, enabling them to make informed

choices about asset management, maintenance scheduling, and resource allocation.

AI and ML are inherently adaptive technologies. They improve over time as they gather more data and learn from their own performance. This means that the longer these systems are in use, the more accurate and efficient they become.

While AI and ML offer promising future solutions, it's equally important to validate SAR practicality and effectiveness through real-world applications. To gain a deeper understanding of how Satellite Technology's Practical Applications in Transport Infrastructure are perceived and utilised within the road asset management landscape.

3.4 Stakeholders in the Space Industry

As noted in the Part 2 – Approach, we were able to discuss this technology with the full supply chain of stakeholders, including creators of satellite infrastructure, regulating bodies, commercial analysts, state road authorities as well as the contractors performing the work on the ground. These interviews provided invaluable insights into the challenges, successes, and future potential of integrating SAR technology into the practices of road authorities and maintenance service providers A summary of the discussions is noted below;

3.4.1 Meeting with the Australian Space Agency (ASA)

Australian Space Agency

Our project team had the privilege of meeting with representatives from the Australian Space Agency (ASA) to gain insights into the current state of the Australian space industry. ASA is at the forefront of driving space-related initiatives in the country, including the development of satellites, space research, and collaboration with international partners. ASA's commitment to fostering innovation and technological advancements in space-related fields aligns with our project's objectives.

ASA Discussion on Applications in Road Asset Management

The meeting was held on the 07-September-2023 with Reece Biddiscombe – Director of the National Space Mission for Earth. Reece is an experienced astronomer with a wealth of knowledge in this sector. Reece has been heavily involved in the space industry all his life, with a 22-year career focused in the Australian Geospatial Intelligence Organisation.

Initial introductions from Reece outlined the ASA's current progress in developments of space research, development of satellites, and the ongoing collaboration with international partners and research foundations. It should be noted, for additional details in this space, ASA have developed an Earth Observation Road Map. This road map is available on their online portal which gives a great overview of the organisation, and in particular where earth observation is headed in Australia.

The team presented the RA Project, and our approach to resolving the issue at hand. It was extremely refreshing and motivating to hear Reece confirm the viability of this proposal. Reece was extremely enthusiastic around the idea, with commentary suggesting that the observation system is already in place, and readily available, however not well utilised in this sector.

> ***"For the sorts of stuff you're talking about, like, hey, it makes so much sense. Australia's got a lot of Road, in the middle of nowhere, why would you have to have people go out and actually physically inspect it if you can get useful observation from somewhere else?" said Reece Biddiscombe.***

Australian Space Agency made it clear there is a detailed collection plan available, and the technology is in place to enable this proposal. The ability of satellite imagery to determine road condition to a degree that is useful, is high. State of the art earth observation is routinely occurring globally, with up to 25cm resolution available from satellites orbiting at a distance of 700km. To further enhance these graphics, Astronomers are also able to use methods such as 'stacking', to overlap images, and lead to what is referred to as a super resolutions in specific areas.

In addition to this, Reece commented on further technology available, referred to as Synthetic Aperture Radar on orbit, using wave pulses, which can provide milli-metric details. This would require targeting the collection and would be able to return details such as a crack in a road pavement.

The ASA confirmed that although Australia does not produce any of its own Observation Data, that is earth observation data is not provided by Australia and we are reliant on other nations. However, these are readily available from global organisations. Given the nature of the work, the fact Australia does not own its own satellites, provides nil financial impact to the purchase of the collection data (recommended sellers include: MAXAR). Although pricing was not discussed in detail, high level figures provided from Reece indicated an order of magnitude cost of $10k - $15k for a bespoke specific footprint (i.e specific timing, cloud density), and circa $2k if willing to take a images from a pre-determined baseline collection plan.

With the project focused on providing relief to resources, this was also discussed at length with the ASA. When questioned about the current resource pool, Reece advised the availability of astronomers and geo-spatial analysts is huge. Earth Observation Australia is world leading in its ability to compile and assess a multitude of different data sets. Once again ASA provided enthusiasm around the proposal, and validated the availability of resources to deliver and analyse the information from earth observation.

"Even though we've got no satellites we've got a yeah ready pumping right earth observation sector and we're we are world leading actually in our ability to get lots of different data sets together and make sense of them. Like that's actually our superpower because we've had to be…" said Reece Biddiscombe.

In summary, the meeting with ASA consolidated that the team's proposal is genuine. With data collections, and resources readily available, to satisfy the intentions of the Roads Australia project. ASA made it clear the intersection of the space industry and road asset management presents a wealth of opportunities for enhanced infrastructure monitoring and maintenance. Satellite technology in particular, holds great promise in transforming the way we manage road assets.

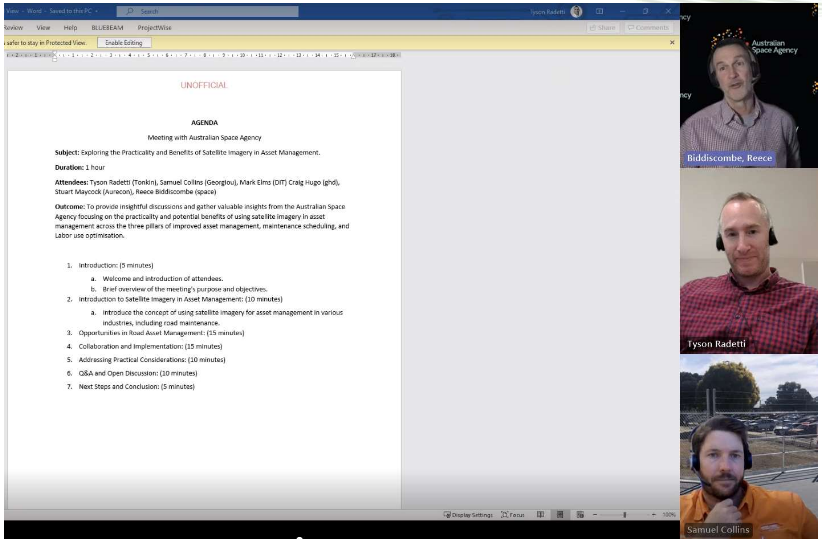

Figure 10 Australian Space Agency Meeting

3.4.2 Meeting with Digital Content Analysis Technology (DCAT)

Our project team also engaged in discussions with Digital Content Analysis Technology (DCAT), a leading provider of satellite data and analytics solutions. DCAT specialises in harnessing satellite imagery, including Synthetic Aperture Radar (SAR) data, to extract valuable insights for various applications. We met with Dr Moira Smith, the Chief Technology Officer, who was able to dial in from Scotland prior to returning to Australia.

Case Studies and Success Stories

As part of our research, we gathered compelling case studies and success stories that illustrate the practical applications of space industry innovations in road asset management:

Case Study 1: Predictive Maintenance

In collaboration with a state road authority, DCAT implemented a predictive maintenance system that utilises satellite imagery to monitor road conditions. By analysing changes in road surface patterns and identifying potential issues, such as cracks or subsidence, the authority was able to proactively schedule maintenance activities, reducing disruptions and costs.

Case Study 2: Flood and Disaster Response

During a severe flooding event in a rural region, satellite data enabled rapid assessment of road damage and access restrictions. Emergency response teams used this information to prioritize rescue efforts and allocate resources efficiently.

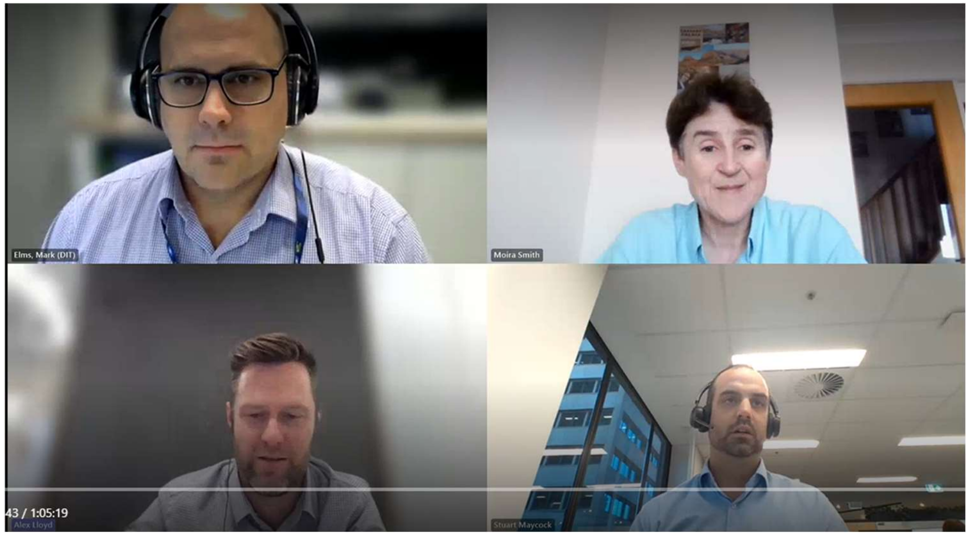

Figure 11 - Digital Content Analysis Technology (DCAT) Meeting

Case Study 3: Environmental Impact Assessment

A major infrastructure project's environmental impact was assessed using space-based data. By monitoring vegetation changes and land use, potential ecological disruptions were identified, leading to adjustments in the project's design and mitigation strategies.

3.4.3 Meeting with DM Roads

DM Roads is a provider of Road Maintenance Services in Australia. The WA/SA team met with, Tim Stanford, Contract Manager SA & Eva Skartados, Business Operations Manager SA around the topic of *"Exploring Satellite Imagery for Enhanced Road Maintenance Services"*.

We discussed the key challenges that DM Roads (Downer) encounters in road asset management and maintenance services, ensuring optimal road infrastructure performance, safety, and cost-effectiveness. Asset and road defect data collection is a very human orientated exercise with boots on the ground collecting defect and asset condition data for the road authority.

DM have used SAR data in the past primarily around pavement deterioration post extreme heat events in Victorian high country. This is where the satellite data monitors the pavement temperature over a period of time and also looks for deterioration in roughness and subsidence. Tim and Eva where aware of its use in the broader Downer Group with Machine Learning and AI in the defence space currently happening.

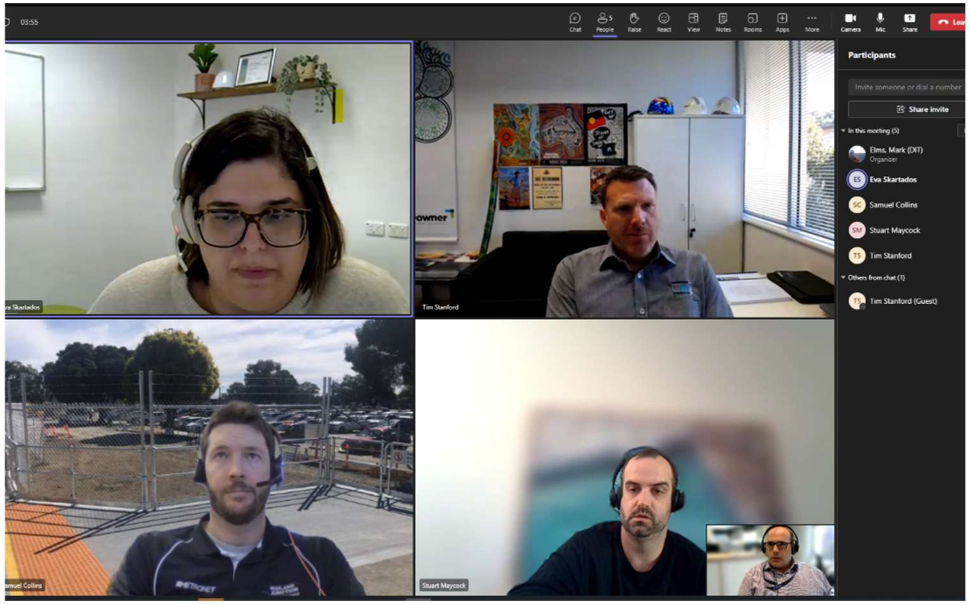

Figure 12- DM Roads Meeting

We reviewed the concept of using advanced technologies, such as satellite data and analytics, to enhance asset management practices, in response to, how real-time SAR satellite data could assist in identifying critical maintenance needs and optimising task scheduling? The feedback was interesting, and several challenges were raised.

“Potentially but it becomes a volume-based issue, it is a nice to have but DM may not be resourced, or DIT not funded to accomplish the work identified. It would also need to take into account DIT maintenance specification with repairs under depicted timeframes for defect rectification, The contractual overlay would be needed”.

On the positive side SAR data would assist DM in emergency response scenarios with rapid impact assessments, were keen to understand if there was an application for ITS data collection. With concerns and obstacles focused around cost, accuracy, flexibility within State contracts.

DM roads currently monitors the roads within their contract area by driving the length of the roads every two weeks just to assess road condition. This is a total of 16,000km driven every fortnight just to assess road condition which could be done remotely. ***Remote monitoring of this area could result in a reduction of 35.36T of C02 emissions in just a single maintenance area***.

3.4.4 Meeting with DIT

Government of South Australia
Department for Infrastructure and Transport

In addition to DM Roads, engaging with DIT towards the end of the project really allowed a practical lens to be applied some of the potential blue sky thinking that is inevitable with new technologies.

The discussion was incredibly useful in understanding the potential for this information. South Australia is one of the smaller states in Australia, but still consists of approx. 13000km of sealed road and 9000km of unsealed road making this technology a very real possibility. Current contract requires these roads to be driven over to once every three months for the sealed network, and every 6-12months for the unsealed road network. Extrapolate that out to other states, and it starts to provide insight into the pure number of hours spent undertaking routine and non-routine maintenance throughout Australia.

Some of the early findings by DIT was that there needs to be further development of the link between the data provided and being able to accurate use the information provided.

It was also evident early on in the discussion that DIT are also in the early phases of starting to understand this technology, having previously sought out information from the industry to obtain detail on the benefits of this technology.

DIT are running two pilot projects, one with DCAT and one with Spottitt.

Project 1 Objectives:

- Surface water movement across roads during flood events with estimation of flooded area including depth & volume.
- Macro Surface Changes – washaways, scouring
- Road Moisture Bands (Outback Roads)
    - For reopening remote unsealed road network to the public
    - Understanding prime moisture conditions for grading

Project 2 Objectives:

- Satellite-Based Pavement Condition Monitoring of DIT Sealed Road Network
    - Analysis ready commercial SAR imagery of DIT sealed road network
    - Establishment of the accuracy of estimated IRI against the measured IRI at 100m or 10m segment level
    - Establishment of the accuracy of estimated PHI against the calculated PHI at the 100m or 10m segment level
    - Condition change calculations with a view to enabling modelling of unique predictive deterioration curve.

“Knowing the data does not instantly mean you know the problem" Mick Lorenz

It is through these investigations that DIT were able to identify a key constraint to implementation being the initial cost and time of the validation of the data. Although the obtaining the required data through the satellite infrastructure, and then analysing the information, it still requires significant amount of work to ensure that the data presented is in fact providing the correct and practical answers.

Using remote road closures for an example, an assessed moisture content level in a road in the North East of South Australia may flag that a particularly road is highly likely to be impassable. When compared to say the Western region of South Australia, that same moisture content may not have a significant impact to the road due to other environmental factors such as differing soil and ground conditions.

Ultimately, the discussion with DIT provided evidence that this is in fact a technology that offers significant benefit to the transport industry, however, the implementation is to carefully consider the challenges to ensure that it does not gain an early perception of the industry losing the engineering grounding within the engineering decision making.

3.5 Challenges and Risks in Implementing Satellite-Based Infrastructure Monitoring

SAR technology, with its ability to capture high-resolution, all-weather images of the Earth's surface from space, has the potential to revolutionise how road authorities monitor, manage, and maintain their infrastructure. It offers a unique vantage point, allowing for real-time, wide-area monitoring, and providing valuable data on road conditions, asset performance, and even environmental factors like soil moisture and temperature. However, the adoption of SAR within road authorities presents a set of complex challenges, each requiring careful consideration and strategic planning.

The integration of SAR into the daily operations of Road Authorities is not a simple plug-and-play. It involves navigating a landscape of technical, financial, and operational hurdles. From data management and interpretation to regulatory compliance and workforce readiness, these challenges are integral to the successful implementation of SAR technology. Team WA/SA also consider how overcoming these challenges can pave the way for a more efficient, data-driven, and sustainable future for Australia's road networks.

While satellite-based infrastructure monitoring offers numerous advantages, its successful implementation is not without challenges and risks. It's imperative to acknowledge and address these potential obstacles to ensure the project's success and maximize its benefits. Key challenges and risks include:

Table 3 - Summary of Project implementation Risks and Challenges

Area	Challenge	Mitigation
Date Privacy and Security	Satellite imagery may capture sensitive or private information, potentially raising data privacy and security concerns.	Implement robust data encryption and access control measures. Ensure compliance with data protection regulations and seek consent where necessary. Work with trusted satellite data providers with strong security protocols
Date Accuracy & Resolution	The accuracy and resolution of satellite imagery can vary, potentially affecting the precision of asset monitoring.	Choose a satellite data provider that offers high-resolution imagery suitable for asset monitoring needs. Employ image processing techniques and ground truth validation to enhance data accuracy. However, this comes at a cost with the with the increase in resolution.
Weather & Atmospheric Conditions	Adverse weather conditions, such as cloud cover or heavy rainfall, can hinder satellite image acquisition.	From our interviews the primary mitigation strategy would be to utilise SAR (Synthetic Aperture Radar) satellites that can penetrate clouds and operate in adverse weather conditions. Combining SAR with optical imagery for a more comprehensive view.
Cost & Budget Constraints	Access to high-quality satellite data can come at a cost, which may strain budgets	Optimize data acquisition plans to balance cost and data quality. Exploring partnerships or collaborations with data providers to access cost-effective solutions
Data Processing complexity	Processing large volumes of satellite data can be complex and resource intensive	Invest in efficient data processing tools and techniques. Consider cloud-based solutions for scalability. Train staff in data analysis and interpretation. There are also companies in the market that can offer these services (DCAT)
Integration with Existing Systems	Integrating satellite-based monitoring into existing infrastructure management systems can be challenging.	Work closely with IT and infrastructure teams to ensure seamless integration. Develop standardised data formats and protocols for interoperability
Skill and Knowledge Gaps	Implementing satellite technology may require new skills and knowledge within the workforce	Provide training and capacity-building programs for staff to enhance their capabilities in using and interpreting satellite data. The skill set is in Australia and as confirmed by ASA, just not currently in the Road sector (4.1)
Environmental and Regulatory Compliance	Compliance with environmental regulations and permits for satellite installations may be required.	Collaborate with regulatory bodies to ensure compliance. Conduct environmental impact assessments as needed and adopt sustainable practices. However, there are growing number of companies that will provide the data which has been run through pre-determined and tested algorithms (DCAT / Spottitt example).
Data Overload (Big Data)	Continuous satellite data collection can lead to data overload, making it challenging to extract meaningful insights	Implement advanced data analytics and machine learning algorithms to automate data analysis and prioritise actionable information. (AI & ML).

4 Innovation Solution and Achieving Project Objectives

4.1 The New Streams of Talent

In order to assess the new streams of talent satellite technology can provide within the road industry; the innovation can be separated into two categories; the collection of data and the analysis of data.

The collection of data is made up of those talent streams involved in the engineering, fabrication and maintenance of satellite technology. Given the high costs of developing and maintaining satellites; it is likely not a realistic option to incorporate these streams into the roads sector.

Discussions with the Australian Space Agency (ASA); see Section 3.4.1; highlighted that Australia does not own/operate the types of satellites required for the collection of large scale data. A number of global organisations can provide this data at a cost; with rates dependent upon the type and resolution of imagery.

The ASA did highlight however that Australia has a robust data analysis sector in the field of earth observation. It is believed that this data analysis talent stream is a realistic occupation which would provide the roads sector with specialist support in the roads maintenance field.

The analysis of large data sets is a developing field with the Australian Federal Government's National Skills Commission (NSC) listing "Data Analytics" as one of "25 Emerging Occupations" in a 2020 report investigating how new skills are changing Australian jobs (NSC, 2020).

The role of data analysts and scientists is to import, inspect, clean, transform, validate or interpret data using algorithms and IT tools.

It is envisioned that road authorities would purchase satellite data such as SAR imagery for further interrogation by data analysts. These analysts would then provide the road authorities with the insights required to more effectively and efficiently manage their road networks. Section 3.3 outlines the many contributions of SAR within the context of asset management and maintenance scheduling; and how when coupled with highly competent data analysts; can optimise labour within the roads sector.

4.2 Alignment with RA Policy Streams

As noted in the strategic plan, Roads Australia strives to achieve a robust integrated transport system for people and products that values and invests in all modes of land transport.

In order to achieve the above, Roads Australia developed five key Policy Streams:

- Capacity
- Safety
- Transport Reform
- Customer Experience
- Sustainability

The premise of the project is to highlight a technical innovation which can be introduced to the Roads Industry to open up opportunities for new streams of talent in our workforce.

The "Capacity" policy stream recognises the need to improve industry and government processes, capabilities and capacity to ensure that the increasing number of transport infrastructure projects are managed and delivered effectively and efficiently.

As outlined in Section 3.3 above, the use of satellite technology optimises labour utilisation by:

- Enhanced Asset Monitoring Efficiency: labour resources can be strategically deployed, focusing efforts where maintenance and intervention are most urgently needed; and
- Predictive Maintenance and Labour Allocation: Data-driven approach optimises workforce deployment, reducing the need for reactive, costly repairs and ensuring that personnel are utilized effectively to uphold infrastructure integrity.

Although the project's innovation primarily encompasses the "Capacity" policy stream, the other policies are also positively impacted through the incorporation of satellite technology into the roads sector:

- **Customer Service:** Greater understanding of asset condition and early intervention can create better roads for all users. Better asset management combined with a proactive approach can drive more cost effective asset management providing benefit to all tax payers.
- **Safety:** Having a better understanding of the asset can trigger early intervention to improve road safety. There is also a significant safety benefit by not having physical site inspections that place vulnerable users within often isolated road corridors.
- **Sustainability:** Along with the direct benefits of less carbon associated with the physical inspection of roads this initiative can also improve resilience in infrastructure by monitoring and managing significant events such as flooding, bushfires and storms.
- **Transport Reform:** The initial phase of this project would not necessarily address transport reform, however future iterations and stages of this initiative could open reform opportunities.

4.3 Diversity and Inclusion

An important objective of Roads Australia is to engage and retain women within the roads sector by improving industry culture and attractiveness through enhanced female representation, flexibility and inclusive procurement practices.

The Infrastructure Market Capacity 2022 Report (IA, 2023) outlined the need for improvement in gender diversity in the construction industry as a whole with approximately 12% women in 2020. When looking at the gender breakdown of full-time female construction employees by occupational group; there is a preference towards project management professionals (36% women), followed by engineering, scientists and architects (19% women).

The incorporation of data analysts into the roads sector is a potential mechanism to attracting women given the National Skills Commission reported that between 2015 to 2019, 32% of the occupation was composed of women (NSC, 2020).

Infrastructure Australia highlighted several factors which contribute to the sectors inability to attract, recruit and retain female employees in the *Delivering Outcomes* report (IA, 2022). Increasing the flexibility of work places is one of these major factors and it is believed satellite technology and data analytics can support this given the remote working nature.

The ability of satellite technology to provide data to an analyst sitting in their home office hundreds of kilometres away from the area of interest, increases the workplace flexibility of staff and potential female recruits.

5 Conclusion & Implementation

5.1 Conclusion

In 2023, the transportation industry is facing significant challenges, including a labour shortage and the need for increased productivity. The report discusses the impact of these challenges, particularly in the Australian context, where the aging workforce and cyclical nature of infrastructure projects contribute to labour shortages and project delays. Infrastructure bottlenecks and congestion are also pressing issues, causing economic costs and inefficiencies.

To address these challenges, the report suggests innovative solutions through the use of earth observation data, via the space industry. It emphasises the integration of technology and automation, such as satellite imagery and data analytics, to enhance asset management, reduce labour-intensive tasks, and improve infrastructure maintenance.

Through research, and interactive interviews with key Space Agencies, the report confirms this technology is already in-place, and readily available. Technology such as SAR from earth observation, delivers the remarkable ability to provide high-quality imaging and to detect even the slightest ground movement with high accuracy. The technical innovation is well developed, available, and waiting to be integrated into the road maintenance and monitoring space.

The report highlights the transformative potential of the space industry and its practical applications in transport infrastructure. It discusses the benefits of satellite technology in data acquisition, analysis, predictive capabilities, efficient resource allocation, and emergency management. These innovations can optimize asset management, maintenance scheduling, and labour use, ultimately improving infrastructure quality and managing costs effectively.

The assessment of the potential talent streams that satellite technology can bring to the road industry can be categorized into two main areas: data collection and data analysis. Data collection encompasses the skills related to engineering, fabrication, and maintenance of satellite technology. However, due to the substantial costs associated with developing and maintaining satellites, it is unlikely that these talent streams can be realistically integrated into the road sector. The data analysis category, on the other hand, is considered a feasible avenue for introducing specialized support in road maintenance. This is because data analysis, particularly in handling large datasets, is a growing field recognized by the Australian Federal Government's National Skills Commission (NSC) as an emerging occupation. Data analysts and scientists play a crucial role in importing, inspecting, cleaning, transforming, validating, and interpreting data using algorithms and IT tools, making them a valuable addition to the road maintenance sector. The capability of satellite technology to deliver data to an analyst working in their home office, even when they are located hundreds of kilometers away from the target location, increases the workplace flexibility of the workforce and potential female recruits.

The project's selected technical innovation shows major alignment with the Roads Australia "Capacity" policy stream, which emphasizes the need to enhance industry and government processes and capabilities for effective management and delivery of transport infrastructure projects. As discussed throughout the paper, the adoption of satellite technology improves labour utilisation by enabling enhanced asset monitoring efficiency and predictive maintenance, optimizing workforce deployment and reducing the need for costly reactive repairs. While the project primarily aligns with "Capacity" policy stream, it has also been demonstrated to positively impacts the other four policy streams of customer service, Safety, Sustainability and Transport reform.

In summary, the report outlines the challenges and solutions in the transportation industry, emphasizing the technical innovation of satellite technology in addressing current issues of labour shortages and productivity issues, introducing new streams of talent to the workface, and delivering on the RA policy objectives.

5.2 Implementation Strategy

Strategy implementation is not always straight forward. The team proposes the following consideration in implementing the technology;

1. More collaboration with the existing companies within the space industry. These collaborations have the potential to then achieve a reduction in implementation costs through the optimisation of the existing infrastructure and technologies. For example, we should carefully evaluate the need to launch new satellites to fulfill specific functions, when existing satellites may be available to provide identical data and information.

2. Identify Cost-Effective Applications. Our focus should be on identifying applications where the technology can demonstrate its cost-effectiveness

quickly. When a business case supports its use, it naturally makes the road to successful implementation a lot smoother. An example of this is explore use in monitoring remote unsealed road moisture content, which when planned correctly with maintenance activities, can significantly reduce water consumption in transportation. Identifying these sorts of use cases can serve as a cornerstone for the development of more frequently employed workflows.

3. There is a need to overcome the roadblock that data validation may be for the technology. Although also linked to costs, providing accurate data is largely linked to the need for on site and real data validation. To this end, there may a need for the end user to recognise that the accuracy of data may not meet the desired levels initially. However, over time, the implementation of machine learning will progressively enhance data accuracy.

4. Authorities must acquire the capability, either in-house or through consultant partners to interpret data effectively. This can be accomplished through strategic partnerships with consulting firms specialising in data analytics or by fostering in-house expertise in data analysis. For the successful implementation of the Satellite technology in the Transport, there needs to be a scenario where data analytics teams and physicists within road authorities can collaboratively interpret the data and present actionable insights to our asset managers.

5. Early acknowledgement by end-users that this technology is being used to supplement existing resources, not replace them, would start to alleviate potential resistance to the adoption of the new technology among the engineers currently in these roles. In addition to this, the development of a user-friendly interface would also be of significant importance to facilitate early adoption.

5.3 Final Statement

The integration of space industry innovations presents a transformative opportunity for road asset management. By leveraging satellite technology and data analytics, we can enhance infrastructure monitoring, predictive maintenance, and response to environmental challenges. Our discussions with the key industry bodies such as the Australian Space Agency and Digital Content Analysis Technology have further reinforced the potential of these innovations in addressing the challenges faced by the transport sector. This innovation is available, well developed, with an available new stream of talent, and waiting to be used to optimise how we do things in the road sector.

Figure 13- Team WA/SA

Figure 14 - Team WA/SA

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