Farming Space Junk

A presentation to Mount Burnett Observatory Members 13 April 2024

By Lachlan Thompson and Anne Brumfitt

Emerald Observatory ASTRIAnet01

Space Optical Tracking Station

Abstract

A behind the scenes insight into Space Situational Awareness (SSA). What is it? Why bother? What are the benefits? Located in Emerald Victoria just 15km from Mount Burnett is the Australian node for the global ASTRIA network of SSA telescopes. This unassuming observatory provides data used by commercial and government agencies for the hazard prediction and risk management of both manned and unmanned space launches.

Figure 1 ASTRIAnet01 the Emerald Observatory. (author)

INTRODUCTION

My wife and I operate a small observatory just 15km down the road from the Mount Burnett Observatory (MBO). Our specific interest is in the farming of space orbital debris or “Space Junk”. The industry buzz word for what we do is called Space Situational Awareness (SSA). We privately own and manage one optical tracking station ASTRIAnet01[1] within a global network of remotely operated and autonomous optical tracking stations that make up what is known as the ASTRIAnet by the University of Austin Texas.

SPACE SITUATIONAL AWARENESS

What is Space Situational Awareness? Space Situational Awareness is knowing what human made and natural objects are orbiting our planet, where they are and where they are going at any point in time. Knowing precisely what is up there and where facilitates a safe and secure placement of satellites and human missions into space.

If you have a military interest the buzz word is “Space Domain Management”. Which is why Australia, has its own “Space Command”. Simply put, the Defense Department gets concerned it may might lose access to a spy satellite or is unable to neutralize a perceived threat to operations. The new command formed in 2021 centralizes government policy formation and capability planning, that enhances cooperation with likeminded allies, and energizes networking with Australia’s rapidly-growing commercial space sector.

The ADF Space Command, was announced in May 2021 (Australian Defense Magazine, 2021), Figure 1, comprises of 150 personnel from the three military services, Defense, and industry contractors. The command works alongside the Australian Space Agency; industry partners; and research and scientific institutions.

The Commonwealth is investing $7 billion over the current decade to ensure Australia’s access to Space, Space services and geospatial information.

[1] Called ASTRIAnet01 as the Australian node was the first of the network of tracking stations to become operational.

Figure 2. Head of Air Force Capability, Air Vice-Marshal Cath Roberts AM, CSC, inside the Electro Optic Systems (EOS) control room at Mount Stromlo Observatory. (Defence)

WHY THE CONCERN?

I was privileged to witness Sputnik, Figure 2, pass over Melbourne in 1957. I was age five when my father rushed into the kitchen shouting “it’s here – Sputnik”. He gathered me up in his arms and we watched this bright silver dot cross the sky. Being an amateur radio operator (Ham), he even recorded Sputnik signal from his amateur band radio.

Figure 3. Sputnik 1. The first human made satellite, launched by the Soviet Union on October 25 1957. (ROSCOSMOS)

From 1 satellite in 1957 we now have today

6,000 satellites in LEO

2,000 active satellites in Earth's Medium orbit

3,000 dead satellites in Earth's orbit

34,000 pieces of known space junk larger than 10 centimetres

128 million pieces of space junk larger than 1 millimetre

(source ESA)

500,000 pieces identified as lethal to both satellite and human

(NASA)

At the 2024, 39th Space Symposium the Deputy Director of NASA Pamela Melroy (Henderson, 2024) explained that, "While keeping U.S. assets like satellites safe is a primary goal – space industry experts and military partners also must prioritize the safety of astronauts as we embark on rapidly advancing our goals in human space travel".

While some of the objects in orbit are large and maneuverable, others are tiny pieces of space debris. That may seem innocuous enough – but when a bolt is flying around the Earth at 17,000 miles (about 27358.85 km) an hour, it becomes incredibly dangerous.

In April 2012, The European Space Agency declared the death of its massive Earth-observing satellite Envisat, Figure 3, after a month of mysterious silence from the school bus-size spacecraft. Envisat was the world's largest Earth-watching satellite for civilian use, with ESA officials touting its 10th anniversary in space earlier in 2012. The $2.9 billion satellite was designed to snap high-resolution photos and radar images of Earth. Envisat managed to provide spectacular images of our rapidly changing earth environment for 10 years, before being knocked out by a 10cent size piece of space debris.

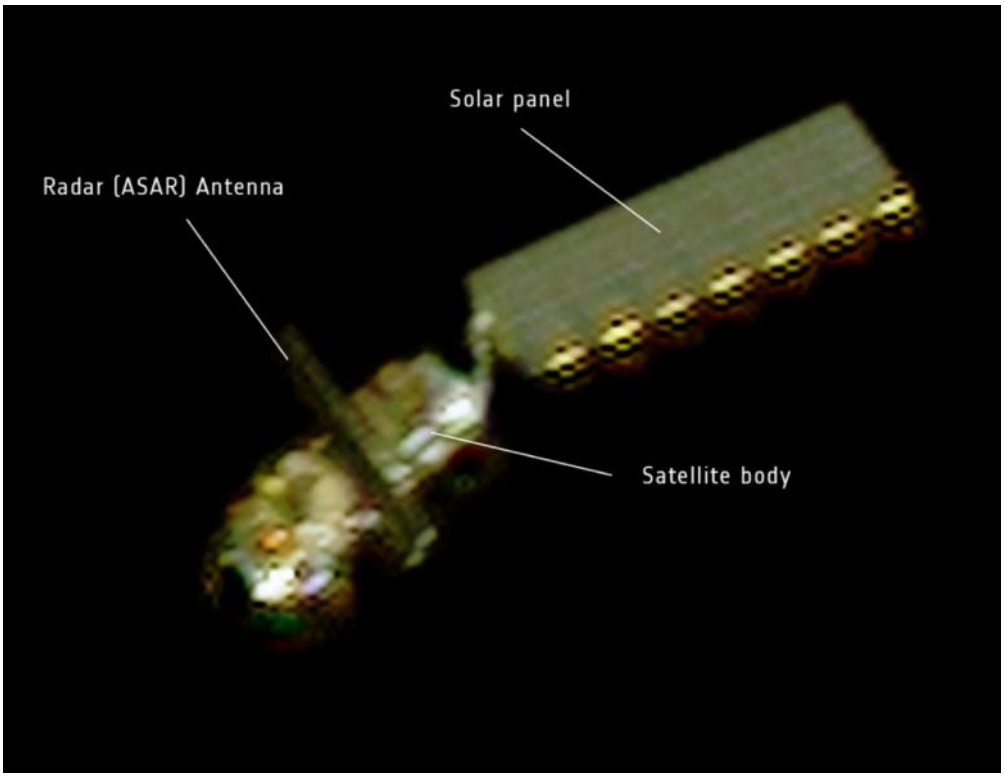

Figure 4. On 15 April 2012, the French space agency CNES rotated the Pleiades Earth observation satellite to capture this image of Envisat. At a distance of about 100 km, Envisat's main body, solar panel and radar antenna were visible. Image credit: (CNES, 2012)

OBSERVING THE NIGHT SKY TODAY

It is ironic that the technology that allows the world to learn of coming night sky events so we all can turn our eyes to the night sky to share and enjoy these events is also destroying it. The spectacular growth (crowding) (J.C.Barentine, 2023) in Low Earth Orbit (LEO) satellites is changing the nature of the space environment. The impact on astronomical observations is starting to be felt. As shown in Figure 4, this image taken through the four-meter telescope at the Cerro Tololo Inter-American Observatory, Chile.

If you are an astrophotographer the future looks pretty sad. The Cero Tololo experience is only the tip of the iceberg. Commercial space companies, including SpaceX, Telesat, Amazon and OneWeb have announced and implemented (Koller-Thompson, 2020) plans to launch large constellations of small satellites into Low Earth Orbit (LEO). This is already resulting in a massive increase in orbital objects. By putting space junk into numbers, we can gain an appreciation of what is to come.

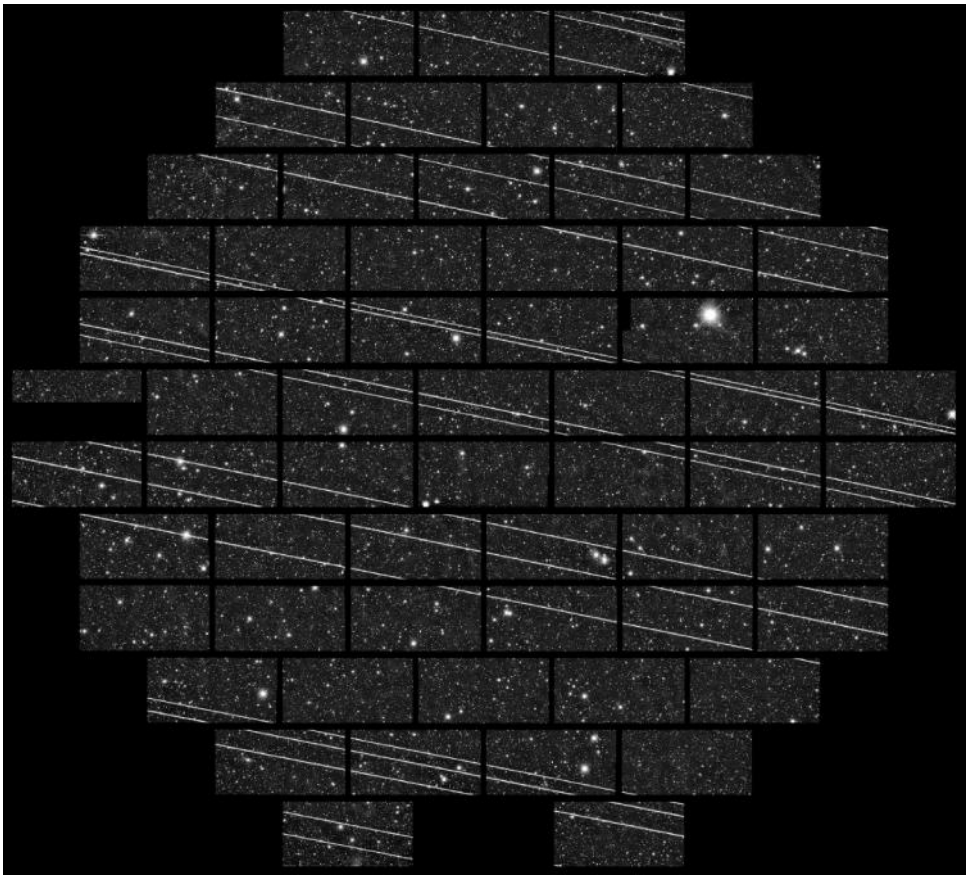

Figure 5. Starlink pollution in a 333-second exposure image taken from the wide field Blanco four-meter telescope at the Cerro Tololo Inter-American Observatory, Chile. (Kashyap, 2021)

STARLINK

SpaceX started launching Starlink satellites in 2019. As of early March 2024, it consists of over 6,000 mass-produced small satellites in Low Earth Orbit (LEO) that communicate with designated ground transceivers. This current array of satellites facilitates internet services only. Starlink on the fourth of January 2024, (Brodkin, 2024) launched its first six mobile phone capable satellites, Figure 5, combining Internet and cellular phone capability.

Figure 6. Launch Cluster of 21 Starlink satellites that include the first 6 Celular Phone capable variants. (Brodkin, 2024)

Space X has announced that nearly 12,000 satellites are planned to be deployed, with a possible later extension to 42,000.

In November 2019 Space X launched its first cluster stack launch comprising of 60 Starlink satellites then formed a visible train, Figures 6 & 7, as they went through separation and systems start up.

Figure 7. The bright tracks of satellites in low-Earth orbit mar this 2.5-minute exposure of the double star Albireo taken in December 2019. By Rafael Schmall. (Sokol, 2021)

Figure 8. In November 2019, a Starlink satellite train was visible over Cerro Tololo in Chile. CTIO/NOIRLAB/NSF/AURA, (Sokol, 2021).

Figure 9. Comet Neowise captured in 17 images each 30seconds by Daniel Lopez. (Edwards, 2020)

Astrophotographer Daniel López experienced the negative impact of the Starlink satellites, Figure 8, (Edwards, 2020) when he took the above photo on July 21, 2020. He shared the image on the Facebook page of his photography company, El Cielo de Canarias, and said it was a shame the satellites had upstaged the comet. The train was still visible in August 2020, Starlink satellite tracks were seen next to comet NEOWISE at Idaho's Craters of the Moon, USA, Figure 9.

Figure 10. In August 2020, Starlink satellite tracks were seen next to comet NEOWISE at Idaho's Craters of the Moon, a national monument. Fifty time-lapse shots, each 4 seconds long, were stacked to make the image. (Sokol, 2021)

Our internet providers keep encouraging us to purchase more cloud storage space where our data is stored on servers somewhere on the planet.

But the virtual cloud has become a very visible orbital space cloud with the planned commercial proliferation of Starlink to over 42,000 satellites and soon to enter Amazon Kuiper satellite constellation with 3,260 plus competitors, Telesat, Oneweb and Microsoft Azure with ?.

TELESAT CANADA

A small but soon to be a contributor is Satellite operator Telesat (Reuters, 2023), has given space tech firm MDA Space a $1.56 billion USD contract

to build 198 satellites for its low-earth orbit program. The launches are scheduled to commence in mid-2026, with polar and global services scheduled to begin in late 2027.

Amazon Project Kuiper

Project Kuiper is an Amazon initiative to increase global broadband access through a constellation of 3,236 satellites in low Earth orbit (LEO). Its mission is to bring fast, affordable broadband to unserved and underserved communities around the world.

ONEWEB

Oneweb rescued from bankruptcy in 2020 by 1billion GBP from the UK govt and private India investment. Now, OneWeb is decidedly back in the mix, with a new CEO and is well on the way to delivering a massive network of 650 low Earth orbit (LEO) satellites to support its broadband offering. The involvement of the UK Government definitely increases OneWeb's gravitas as a safe bet.

UK Secretary of State for Business, Energy and Industrial Strategy Alok Sharma, commented last year: "Access to our own global fleet of satellites has the potential to connect people worldwide, providing fast UK-backed broadband from the Shetlands to the Sahara and from Pole to Pole. This deal gives us the chance to build on our strong advanced manufacturing and services base in the UK, creating jobs and technical expertise."

SPACE TRAFFIC MANAGEMENT

With the proliferation of LEO objects the accurate knowledge of where each satellite is and where it is going to be is paramount to collision avoidance. Complex mathematical models, Figure 10, using the data gathered by ASTRIAnet and space agencies facilitates avoidance mechanisms such as the phasing of satellite constellation orbits (Yanikomeroglu, 2021).

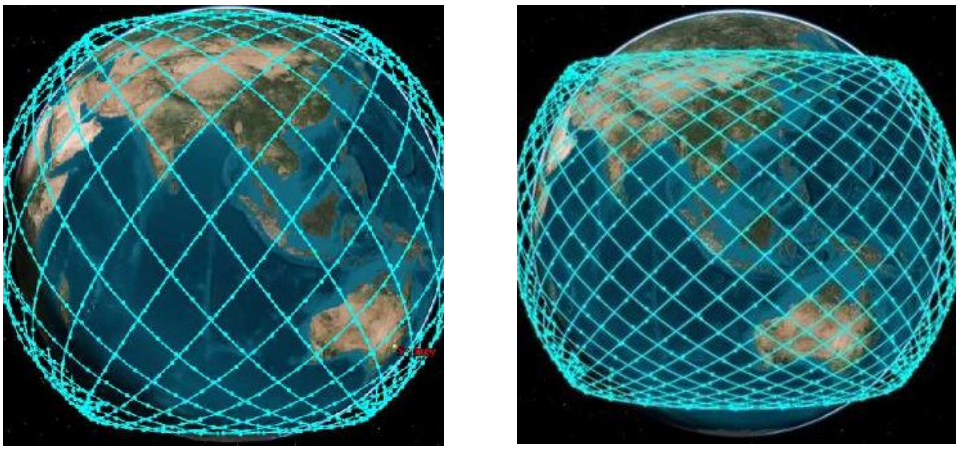

Figure 11. Visual graphic of the simulated phasing of 6,000 satellites, comprising of 3000 Starlink (left) and 3000 Kuiper Satellites (Right). (Yanikomeroglu, 2021).

The time for International Space Traffic Management Is Now. Research conducted by the RAND Corporation's key finding was that.

"The international community is at a tipping point for STM. Research strongly indicates that the space domain's safety and sustainability are under clear and present threat from debris and congestion. Because of this threat and because the space domain involves international actors (or entities under the jurisdiction and control of states), an international organization is needed to conduct STM". (Bruce McClintock, 2023)

The report went on to recommend that, "To accomplish this, the authors recommend that spacefaring and nonspacefaring states call for an International Space Traffic Management Organisation convention to be held at the United Nations (UN)." (Bruce McClintock, 2023)

ASTRIANET A KEY TOOL FOR SPACE TRAFFIC MANAGEMENT

ASTRIAnet is a set of optical tracking stations in strategic locations on the planet. The data provided by the ASTRIAnet tracking stations is combined with US government, ESA and other space agency data to produce and validate the ASTRIAgraph orbital path prediction software model. Dr Moriba Jah, is the architect of the AI driven ASTRIAgraph computational model, Figure 11, to accurately predict the trajectory of satellites (Jah, 2024) and identified debris. The software can predict collisions and the likely resulting debris cloud. Higher resolution variants of the code are offered to government and private companies on a commercial basis.

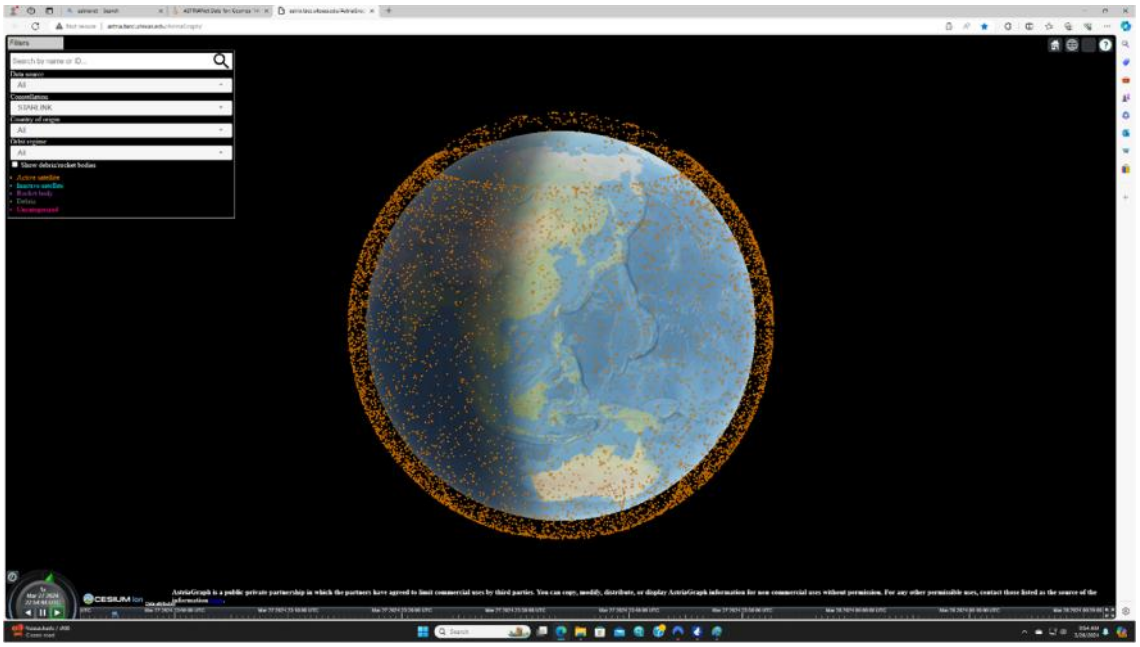

Figure 12. ASTRIAnet and Space Agencies data of the Starlink constellation in Astriagraph as of 10 April 2024, at the University of Austin Texas website. (Jah, 2024).

One of note is Privateer founded by Steve Wozniak of Apple Computer fame and Engineer Alex Fielding. This commercial user offers the ASTRIAgraph model under the product name Wayfinder, Figure 12.

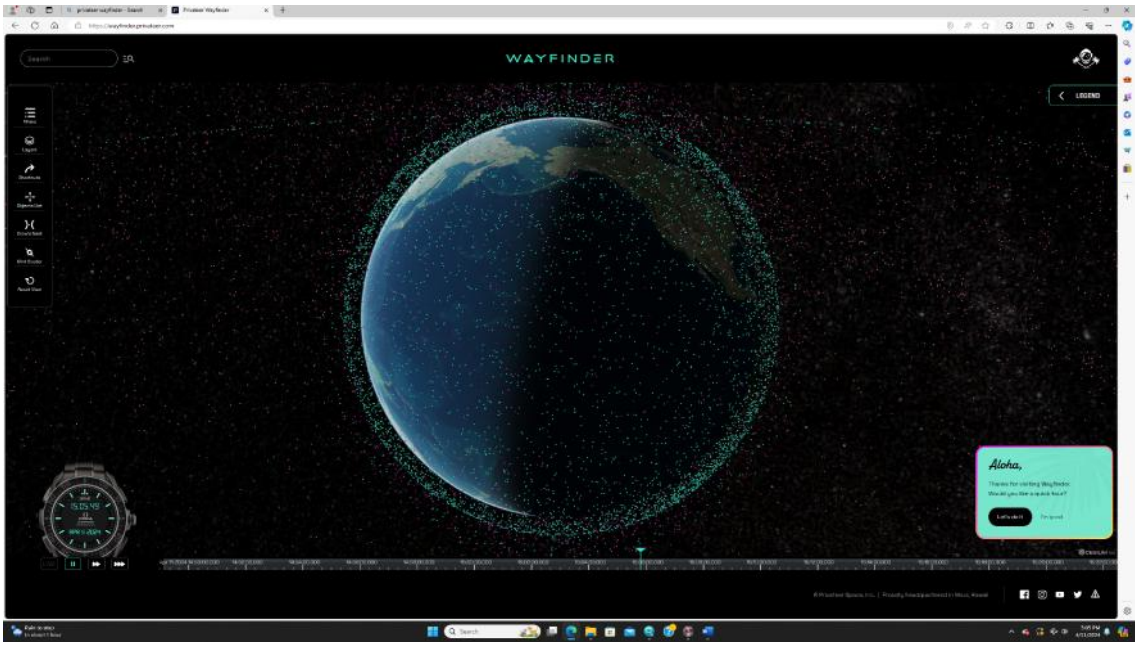

Figure 13. Wayfinder is a commercial development of ASTRIAgraph using ASTRIAnet data within mathematical model developed at University of Austin Texas by Moriba Jah and his research team. (Privateer Space, 2024)

THE FUTURE

So where does this all lead? Simply put there are going to be more objects in LEO once there is an internationally agreed method of Space Traffic Management. Like sea navigation and air navigation already have a method of internationally agreed traffic management there will evolve through the United Nations (Werner, 2021) an internationally standardized means of Space Traffic management. “There is a huge need to stabilize global space operations through norm generation and multilateral consensus,” Simonetta di Pippo, director of the UN Office for Outer Space Affairs, “We must future-proof activities now to deliver a safe, secure and sustainable space environment for tomorrow.”

When ESA or NASA predict a One in 10,000: risk of collision then the ISS is instructed to take debris avoidance maneuvers. The path to collision avoidance is mathematically calculated taking into consideration the flight path of all known objects in its path. There have been 25 debris avoidance maneuvers by the ISS since 1999.

In the mean time while the UN and the world’s nations work this out. SpaceX is using AI for navigation of the Starlink satellites. SpaceX’s satellites have built-in sensors that guide them in space and prevent them from collisions with debris and other alien objects in space. The AI systems in satellites discover the predictive patterns for planets, debris and other satellites. However, in the past year, there have been multiple instances of SpaceX’s Starlink almost colliding with other satellites. SpaceX’s Starlink satellites alone are involved in about 1,600 close encounters between two spacecraft every week, that’s about 50% of all such incidents (Pultarova, 2021).

The current 1,600 close passes include those between two Starlink satellites. Excluding these encounters, Starlink satellites approach other operators’ spacecraft 500 times every week. This is with only 6000 satellites.

What will it be like with 42,000?

Figure 14. Is this the future for wide field astrophotograpy? The Starlink train is running top to bottom, stars rotating about top left corner. (anonn, 2024)

The future of widefield astrophotography, Figure 13, is at best uncertain.

EMERALD OBSERVATORY ASTRIANET01

What is inside the Emerald Observatory ASTRIANET01? For the technical we house a Planewave CDK20 f3.4 operating on a Planewave L500 mount. Imaging is via an FLI Keppler 400 with an FLI filter wheel housing Astrodon Full Frame filters using the Hubble Grouping. For wide field imaging we use a piggyback Canon 200mm USM f1.2 lens fitted to a Starlight Trius 814 ccd camera controlled by an ISSI focuser. All housed under a Scopedome 3metre dome.

The circular building below is rendered Heble brick 3metres high and houses the required computing, ethernet and UPS equipment. The building including the Scopedome is designed to Bushfire Level 25.

IRONICALLY the Australian ASTRIAnet station employs Starlink for the highspeed internet transmission of images and data. On a slow night we will have a typical upload speed of 120mbps with download 900mbs. Making Australia the fastest responding to command ASTRIAnet tracking station

with an apparent instantaneous response to operational commands from Austin Texas.

Amusingly the much closer to Austin Texas sister stations in New Mexico and Chile have a considerable time lag (This prompted one of the operators based in Austin Texas to say, “Wow this is fast. With the other nodes you have time to go and get a McCoffee between command and response”). The Emerald Australia station is the only ATSTRIAnet tracking station to use Starlink.

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