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Space Situational Awareness with CSIRO's Radio Telescopes

CSIRO Space & Astronomy and CSIRO Data61

CSIRO owns and operates a range of **world-class radio telescope facilities** around Australia—each with extremely sensitive receiving systems, broad spectrum coverage, and massive signal processing capability. As new telescopes such as the Square Kilometre Array are commissioned, older **instruments become more available**. A team has formed at CSIRO to investigate how this excess observation time can be used to **contribute to space situational awareness** (SSA).

Through **experimentation** and progressive **system augmentation**, the team seeks to establish the strengths, weaknesses, unique abilities, and hard limitations of CSIRO's radio astronomy hardware as applied to SSA.

CSIRO's Radio Telescopes

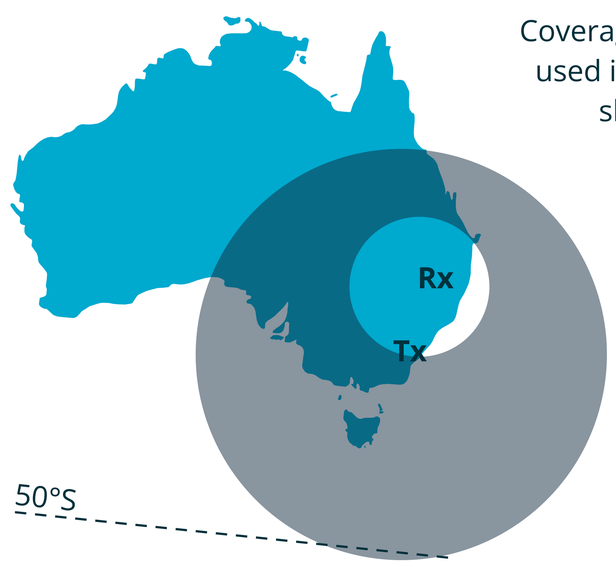
Facility	Diameter	Frequency Range
Australia Telescope Compact Array	6 x 22m	1.1 – 105 GHz*
Giyalung Miil Parkes Telescope	12m	0.7 – 4GHz
Mopra Radio Telescope	22m	1.1 – 117 GHz*
Murriyang Parkes Radio Telescope	64m	0.7 – 4 GHz

*Indicates that frequency coverage is across noncontiguous bands.

Observation time using these facilities is allocated to researchers based on scientific merit, but up to 50% is available for **externally-funded sessions**.

Why use radio telescopes for tracking?

Radio telescopes designed for astronomy have unique strengths even compared to dedicated SSA instruments, including: **high sensitivity**, **broad bandwidth and band coverage**, and the ability for **multiple calibration methods** to be used—flux density, timing, phase difference, and more. They are also supported by **significant compute resources** for signal processing.



Coverage of the bistatic radar configuration used in experiments (Tidbinbilla-Narrabri), shown for objects at 1000km altitude.

Australia-based instruments have the potential to supplement SSA data collection across southern latitudes which historically have the **poorest coverage** [1].

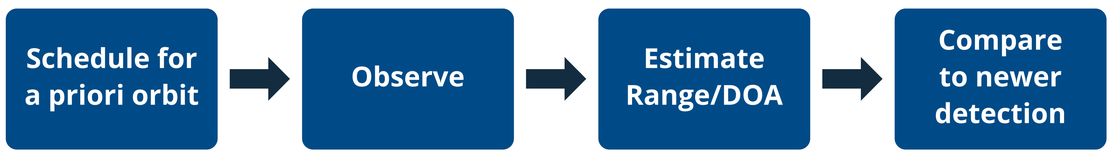
Despite a broad field of regard, instantaneous FOV is extremely narrow. For SSA applications, this high angular resolution means **precise directional information**.

Focus of Investigation

Early work has targeted the **Australia Telescope Compact Array** (ATCA), a six-element interferometer consisting of 22m Cassegrain reflector antennas that are track-mounted for configurable baseline separation. As a receive-only system, ATCA is suited to passive RF surveillance for characterising **active objects and emissions**; when paired with a suitable transmitter in a bistatic arrangement, it is a highly sensitive receiver for observing **debris reflections**.

Initial investigation focused on the ability for **current processing tools** to yield SSA-relevant data, and identifying **systematic errors** introduced by astronomy-first data pipelines—where near-field or fast-moving objects are not considered.

Tracking Resident Space Objects



Observations begin by propagating a prior TLE for the target object. Experiments prioritised objects for whom **a priori orbit information** was thought to be most accurate—frequently-detected objects such as GNSS satellites or large debris.

Position inference was then done on the resulting data using a bespoke three-dimensional implementation for the **MUSIC direction-finding algorithm**. The resulting object position in that instant—as well as a refined orbit as produced by an **extended Kalman filter**—were compared to a more recent ephemeris or back-propagated TLE to produce a final measure of accuracy for each detection.

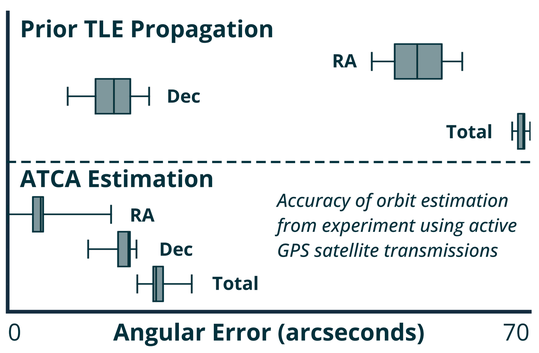
System Performance

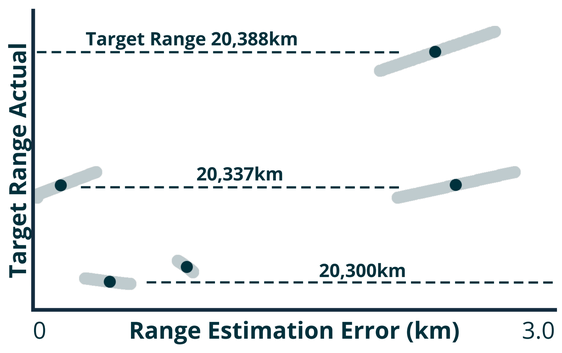
So far these methods have been used to successfully detect:

- **medium to large debris objects** via **bistatic radar** [2, 3]
- **transmitting satellites** via **passive RF monitoring** [4]
- targets at high altitudes in **tracking mode**, other objects in **beampark mode**

The mechanical **slew speeds** of astronomical telescopes were designed primarily to account for the rotation of the Earth during long observations of static objects. Thus, slower-moving targets were selected from **MEO and above**.

Systematic errors were identified—including a **phase offset** which scaled inversely with object range. Once these errors were accounted for, angular position estimation typically came **20-60% closer to the target** than prior TLE propagation. However, **precise range estimation** remains an issue.





Where to next?

The outcomes of this phase inform plans for SSA-specific additions to ATCA's software and hardware. Efforts to augment existing astronomy pipelines with **SSA-focused processing tools** is ongoing, and hardware that will allow access to **pre-processed data** is scheduled for installation in early 2024.

Current Limitations and Future Work

Some properties of CSIRO's radio astronomy instrumentation would require more significant hardware changes to remedy—such as **slew speeds** imposing limitations on what continuous tracking can achieve, based on pass duration and object altitude. Others require cooperation, such as the need for an **external transmitter** to operate in bi-static mode.

Efforts to make use of fringe pattern analysis for **uncued detection** and precise **orbit refinement** are underway. Further experimentation and collaboration is sought, to explore the **unique capabilities of radio telescopes**, investigate **additional modes of operation**, and **enhance data processing tools** for SSA.

1. M. Buttfield-Addison, A. Hellicar, and J. Montgomery, "**Projected Benefits and Opportunities for Increased Southern Hemisphere Contribution to Space Situational Awareness**", in *43rd COSPAR Scientific Asssembly*, Jan. 2021.

2. H. Nosrati, S. Smith, D. Hayman, and S. Horiuchi, "**Bi-Static Radar Interferometry for Space Debris Localisation using Australia Telescope Compact Array**", in *Progress in Radar Research*, Feb. 2022.

3. H. Nosrati, S. Smith, D. Hayman, S. Horiuchi, A. Hellicar, and K. Smart, "**Bi-static Radar Interferometric Localization of MEO and GEO Space Debris using the Australia Telescope Compact Array**", in *23rd Advanced Maui Optical and Space Surveillance Technologies (AMOS) Conference*, Sep. 2022.

4. H. Nosrati, S. Smith, and D. Hayman, "**Space Observation by Australia Telescope Compact Array: Performance Characterisation using GPS Satellite Observation**", in *73rd International Astronautical Congress (IAC)*, Sep. 2022.

Check out Space Situational Awareness at CSIRO →

Chat with **Ken Smart** here today, or contact the SSA project leader at stephanie.smith@csiro.au to learn more or **propose a collaboration**.