Space Situational Awareness in Australia:

Overview & details of the Space Environment Research Centre

James C. S. Bennett

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Space Asset Management Program Leader, Space Environment Research Centre, ACT, AUSTRALIA

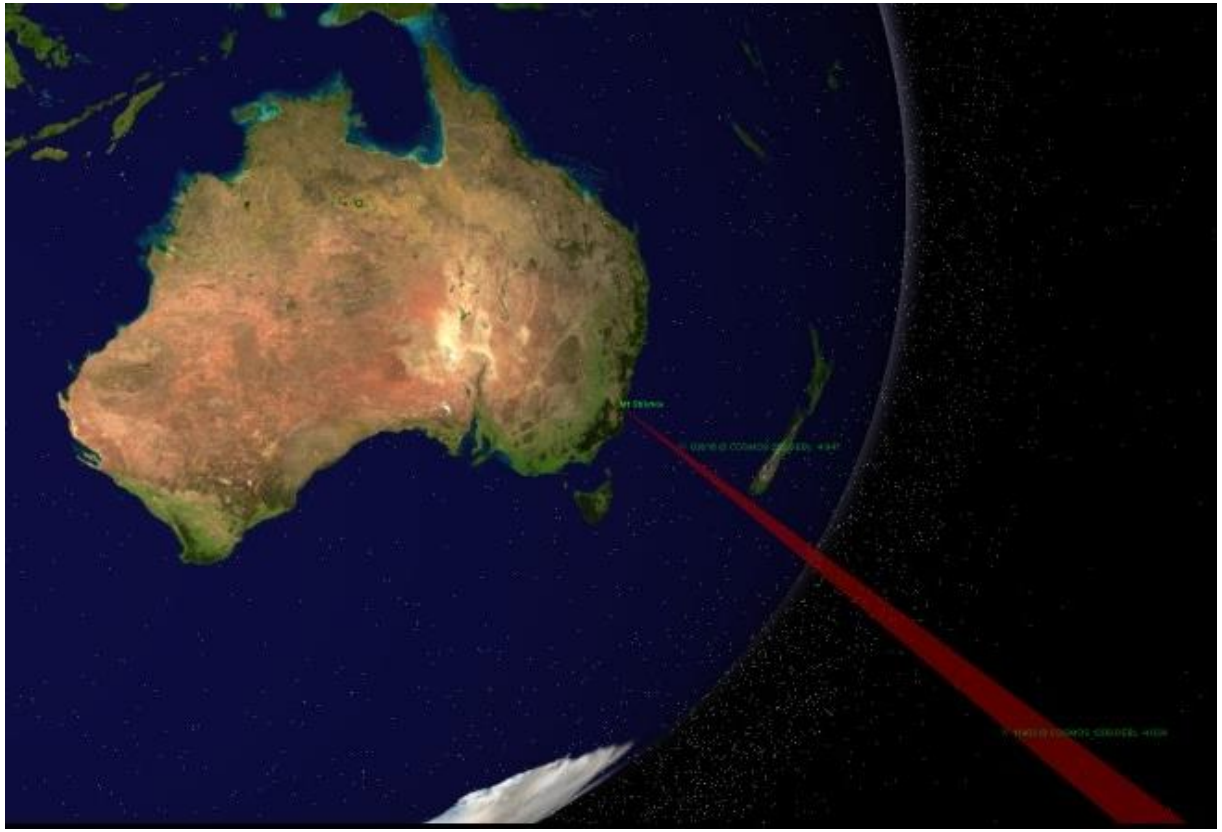
Space Situational Awareness Workshop: Perspectives on the Future Directions for Korea, January 24 – 25, 2019

Australian Government
Department of Industry, Innovation and Science

Business Cooperative Research Centres Program

Overview

- Brief introduction to Space Situational Awareness
  - Conjunction assessment: South Korean satellites
- Introduction to Australia's space industry
- Overview of major Australian programs
- Detail on the effort at SERC & EOS
  - Our approach to SSA
- Conclusions



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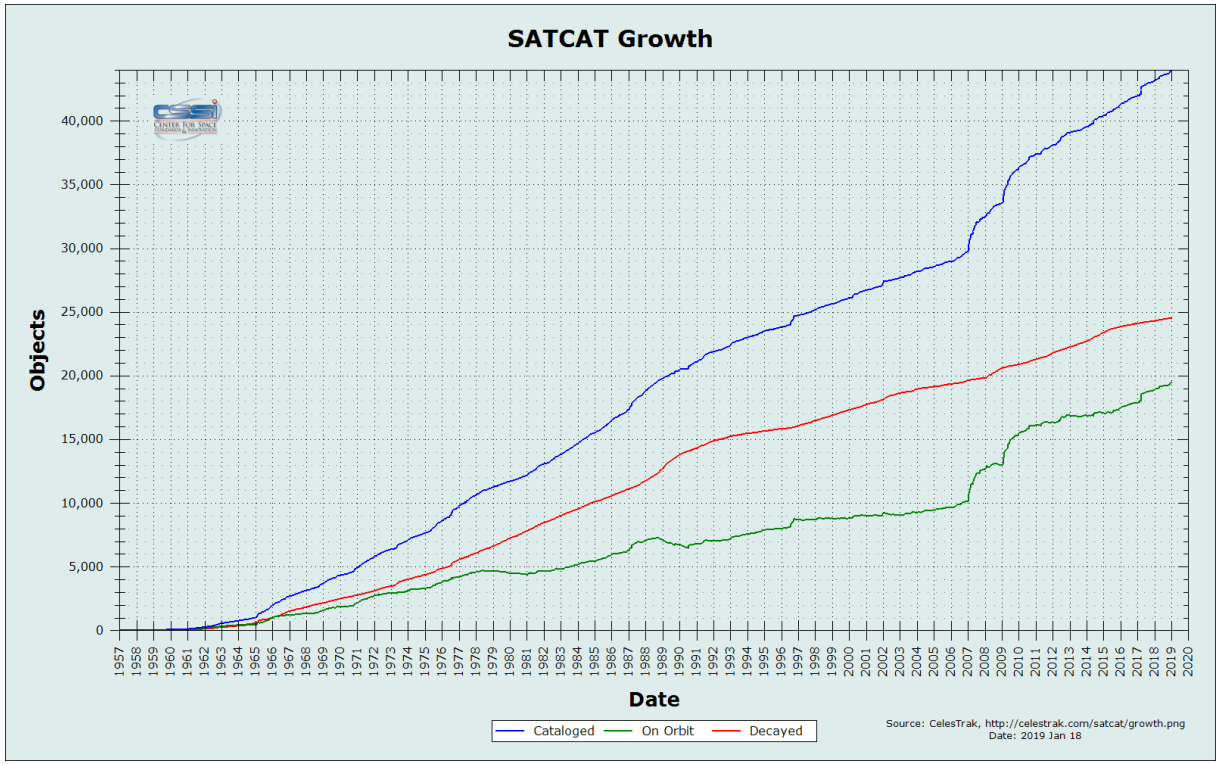
Space Situational Awareness

- Space is becoming increasingly congested & contested
- Changing environment:
  - Mega constellations
  - Improved access
  - New space players, inexperienced
- Mitigation & remediation needed
- Space Traffic Management



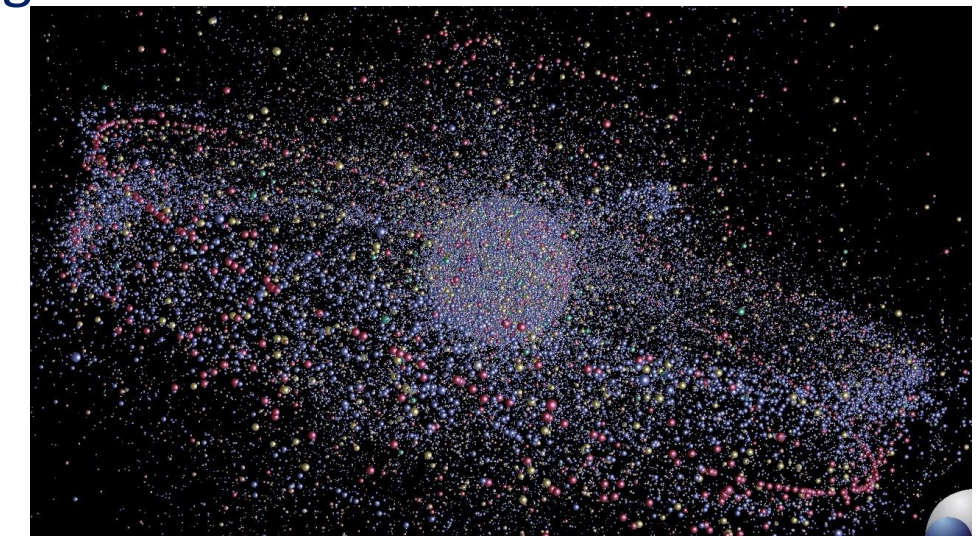
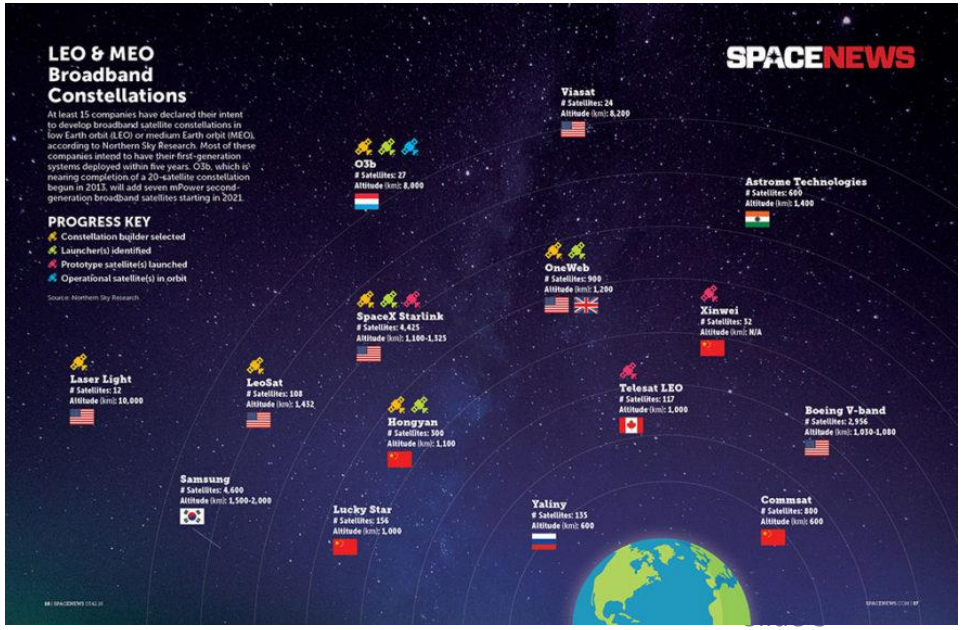


Image credit: Marek Möckel, SERC



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Some core SSA components…

Sensors
- Detect
- Track
- Taskable network
- Distributed
- Multiple sensors types
- Efficient Scheduling
- Automation

Database/catalogue
- Observations
- Astrometrics
- Track associations
- Data validation
- Traceable
- Object characteristics

Environment
- Space weather
- Force Modelling
- On-orbit object population
- Breakup modelling

Data fusion / analyses
- Close approach
- Proximity
- Manoeuvre detection/planning
- Breakup detection
- Geomagnetic disturbance forecasts
- Re-entry
- Data analytics

Object knowledge
- Ephemeris
- Error covariance
- Light signatures
- Ballistic/radiation coefficients
- Size, mass, material…
- Payload, R/B, Deb
- Active?
- Attitude dynamics
- Manoeuvrability

Integrated Systems

SSA fundamental to command-and-control capability

⇐ Actionable SSA knowledge ⇒

⇓ Decision

Intelligence
Information superiority
Asset protection
Space Traffic Management
Space policy / law
Missile Defence

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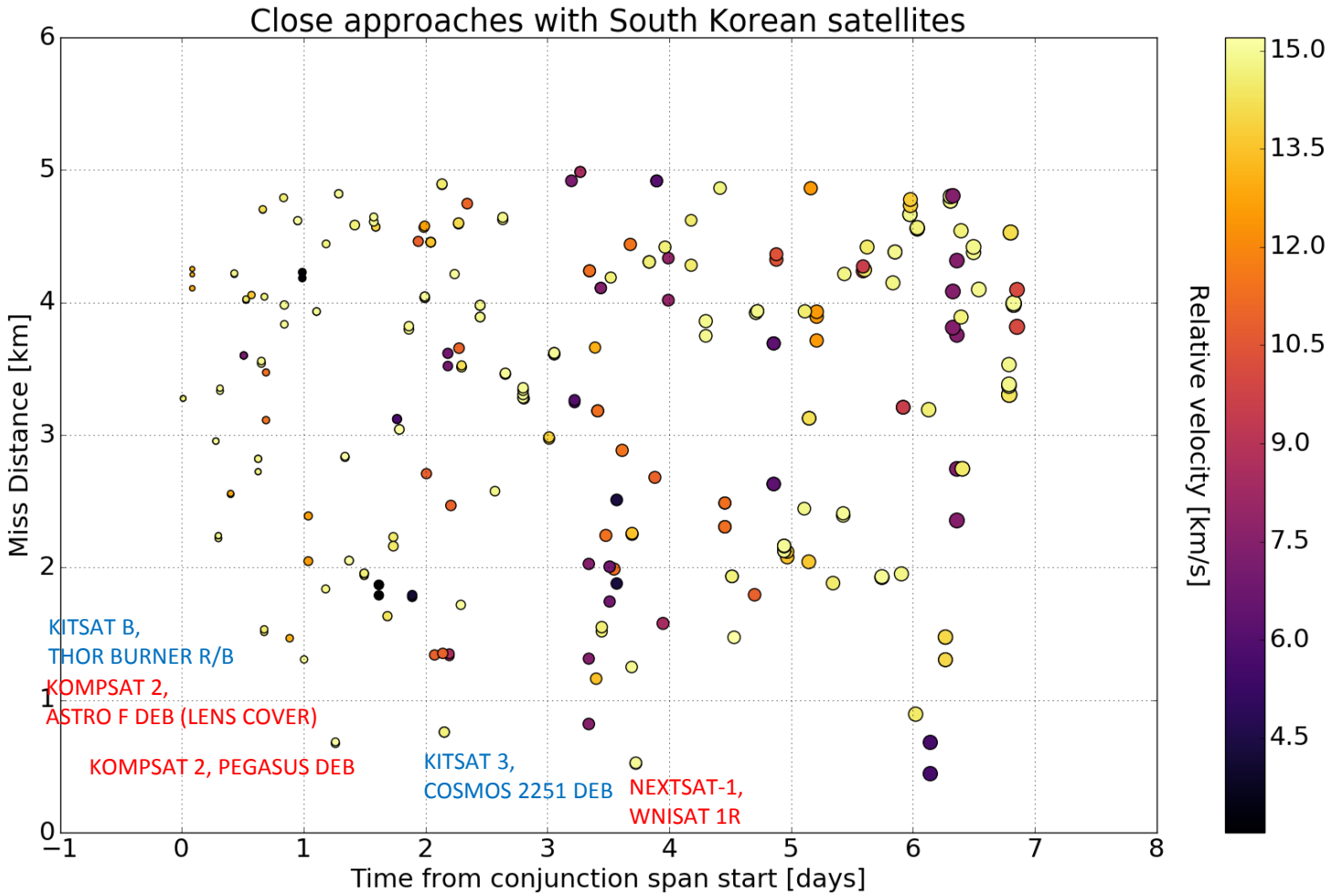
Example: Close approaches



2018-Jan-17 00:00:00 – 2018-Jan-24 00:00:00

Conjunction analysis, restricted to approaches <5km

INTLDES	NORAD ID	STATUS	SATNAME	Period	INCL	APOGEE	PERIGEE
1992-052B	22077	-	KITSAT 1 (KO-23)	111.9	66.1	1317	1313
1993-061F	22828	-	KITSAT B	100.7	98.9	797	782
1995-041A	23639	-	KOREASAT 1	1444.9	14.2	35984	35932
1999-029A	25756	-	KITSAT 3	99.1	98.4	722	705
1999-070A	26032	-	ARIRANG-1 (KOMPSAT-1)	98	98	666	661
2003-042G	27945	-	STSAT-1	98.3	98	686	670
2006-031A	29268	+	ARIRANG-2 (KOMPSAT-2)	98.5	98.1	698	673
2006-034A	29349	+	KOREASAT 5 (MUGUNGWHA 5)	1436.2	0	35789	35787
2010-032A	36744	+	COMS 1	1436.1	0	35788	35786
2010-070B	37265	+	KOREASAT 6	1436.1	0	35794	35781
2012-025B	38338	+	ARIRANG-3 (KOMPSAT-3)	98.5	98.2	694	681
2013-003A	39068	+	STSAT-2C	92.4	80.2	527	259
2013-003B	39069		KSLV-1 R/B	97.9	80.2	1035	284
2013-042A	39227	+	ARIRANG-5 (KOMPSAT-5)	95.7	97.6	554	552
2013-066G	39422	+	STSAT-3	96.7	97.6	616	582
2015-014A	40536	+	KOMPSAT-3A	95.2	97.5	538	521
2017-023A	42691	+	KOREASAT 7	1436.1	0	35793	35780
1998-067MG	42727	+	SNUSAT-1	90.8	51.6	313	311
1998-067MN	42733	+	SNUSAT-1B	90.6	51.6	303	302
2017-067A	42984	+	KOREASAT 5A	1436.1	0	35794	35779
2018-004AD	43138	-	STEP CUBE LAB	94.5	97.5	503	488
2018-099AA	43782	+	SNUSAT-2	96.3	97.8	592	573
2018-099BF	43811	+	NEXTSAT-1	96.3	97.8	591	571
2018-100A	43823	+	GEO-KOMPSAT-2A	1436.1	0.1	35789	35784

Australia's Space Industry

- Australia's space industry employs 10,000+ people across approximately 400 companies
- The Australian space industry is worth approximately $4 billion
  - Defence: $175M
  - Non-Defence Government: $126M
  - University Research $44M
  - Commercial: **$3.598 billion**
- Drive growth to $10-12 billion per year by 2030, employing 20,000+ skilled staff

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Australian Space Research Program (2010–2013)

- $40 million over 4 years
- A total of 14 projects across 2 streams:
  - Space Education Development
  - Space Science & Innovation
- Final evaluation carried out by Ernst & Young: https://www.spaceindustry.com.au/Documents/Final_evaluation.pdf
- Capability delivered from ASRP still in use today

Australia's Satellite Utilisation Policy

- Released in 2013

The Australian Government took important steps towards developing a coordinated space policy in releasing the *Principles for a National Space Industry Policy*. The principles are:

1. Focus on space applications of national significance
2. Assure access to space capability
3. Strengthen and increase international cooperation
4. Contribute to a stable space environment
5. Improve domestic coordination
6. Support innovation, science and skills development
7. Enhance and protect national security and economic wellbeing

Source: https://www.industry.gov.au/data-and-publications/australias-satellite-utilisation-policy

Australian Space Agency

- Announced at The 68th International Astronautical Congress, IAC 2017, Adelaide
- Established 1st July 2018
- $41 million over 4 years
- Headquarters in Adelaide (12th December announcement)

Priorities

The national civil space priorities focus on strengthening Australia's competencies and growing capabilities. They include:

- *Communications technologies, services and ground stations*
- *Space Situational Awareness (SSA) and debris monitoring*
- *Positioning, Navigation and Timing (PNT) infrastructure*
- *Earth Observation (EO) services*
- *Research and development*
- *Remote asset management*
- *Developing a strategy to position Australia as an international leader in specialised space capabilities*

Australian Space Agency

(source: https://www.industry.gov.au/strategies-for-the-future/australian-space-agency)

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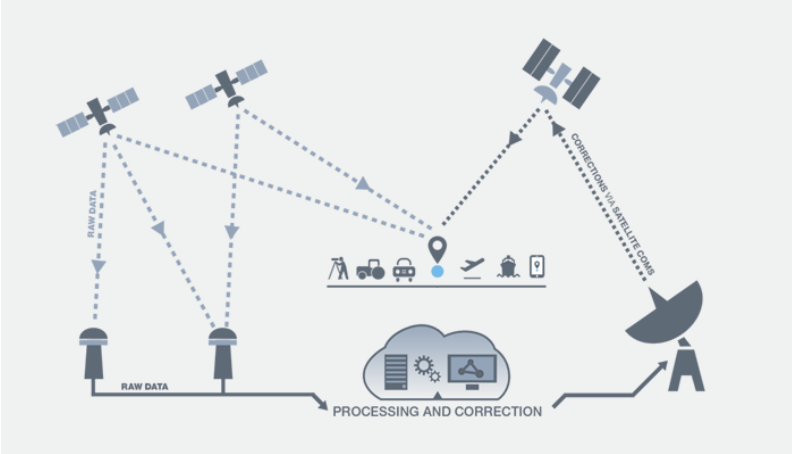
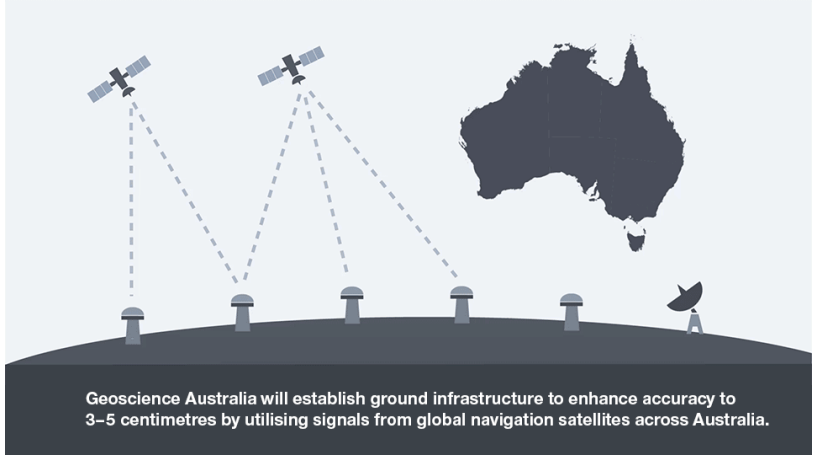
Space Infrastructure

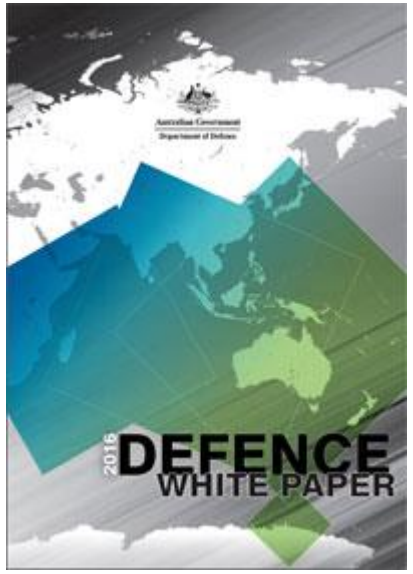
- $161M for a Satellite Based Augmentation System
  http://www.ga.gov.au/scientific-topics/positioning-navigation/positioning-for-the-future/satellite-based-augmentation-system
- $64M for National Positioning Infrastructure project
  http://www.ga.gov.au/scientific-topics/positioning-navigation/positioning-for-the-future/national-positioning-infrastructure
- Additional $37M for over the next 4 years for Digital Earth Australia
  http://www.ga.gov.au/dea





Defence

Source: http://www.defence.gov.au/Whitepaper/



- Next Generation Technologies Fund
  - Focussed on emerging and future technologies
  - $730M over 10 years to 2026
- Defence Innovation Hub
  - Initiative of 2016 Defence Industry Policy Statement
  - Investment of $640M over 10 years to 2026
  - Space situational awareness part of priority 1 for the 2018-19 financial year

- Sovereign Industrial Capability Priority Grants
  - Announced in 2018 Defence Industrial Capabilities Plan
  - Annual grants program up to $17M for SMEs
  - Aligned with Sovereign Industrial Capability Priorities
  - $50,000 to $1M with 50:50 matched funding for acquisition of capital equipment

  Source: http://www.defence.gov.au/SPI/Industry/CapabilityPlan/SICP-Grants.asp

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Cooperative Research Centre for Space Environment Management

- Announced 7th March 2014, operational mid-2014
- Industry-led (EOS Space Systems)
- $60M over 5 years:
  - $20M from Australian Government
  - $40M private investment from CRC participants
  - $90M of research infrastructure allocated from CRC participants
- Space Environment Research Centre (SERC) founded

The Space Environment Research Centre

Founding Participants

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Australian National University

RMIT UNIVERSITY

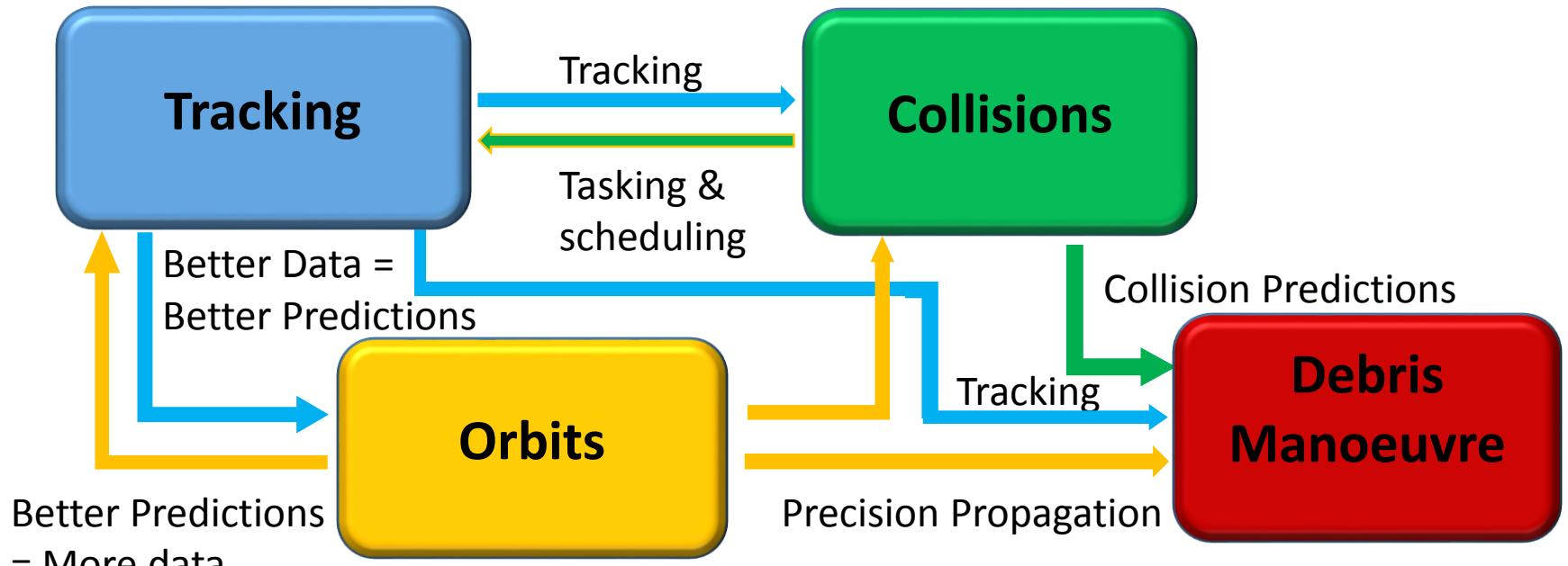
Australian Government Department of Industry, Innovation and Science | Business Cooperative Research Centres Programme

OPTUS yes

LOCKHEED MARTIN

NICT National Institute of Information and Communications Technology

SERC Research Programs



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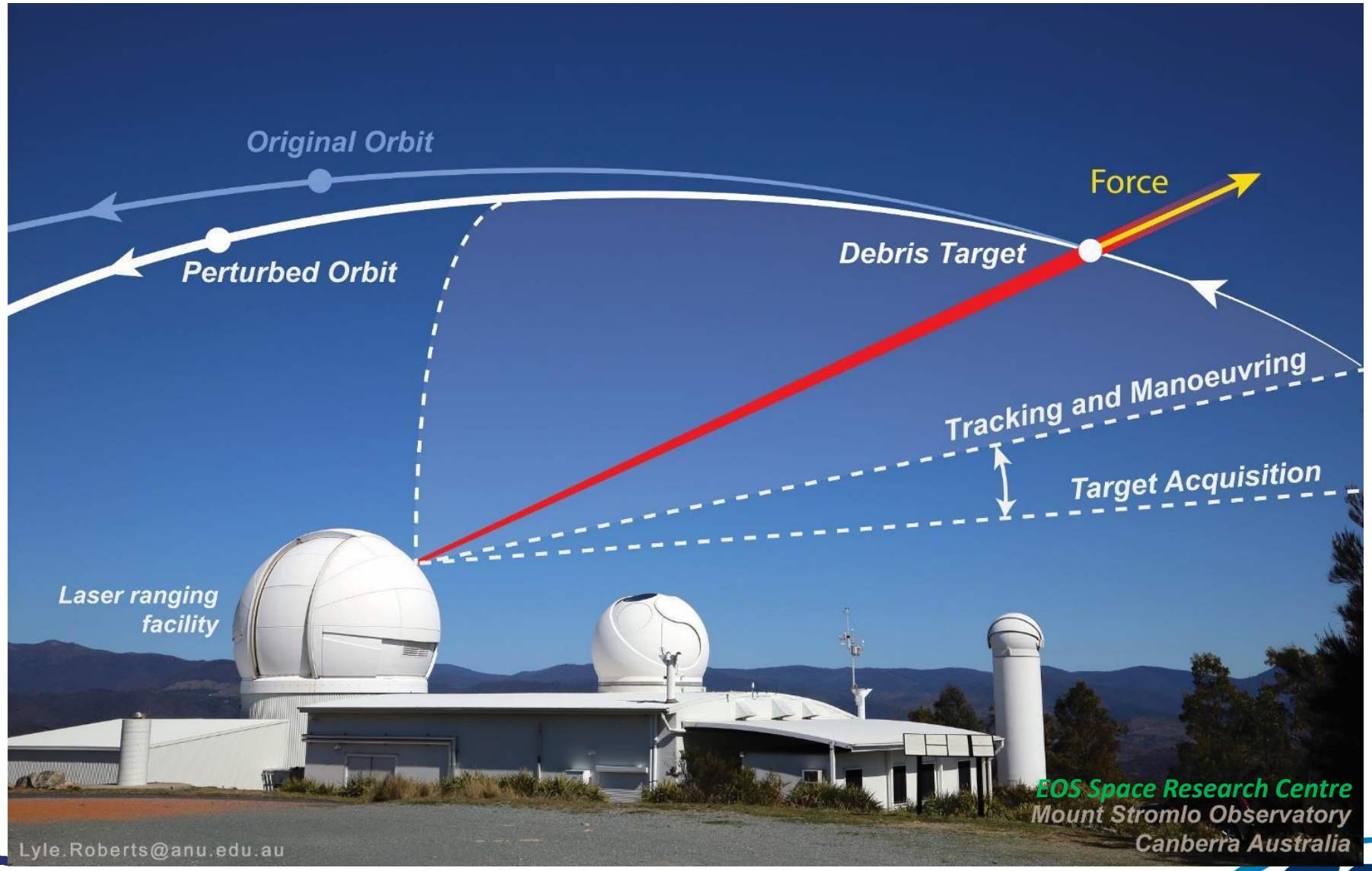
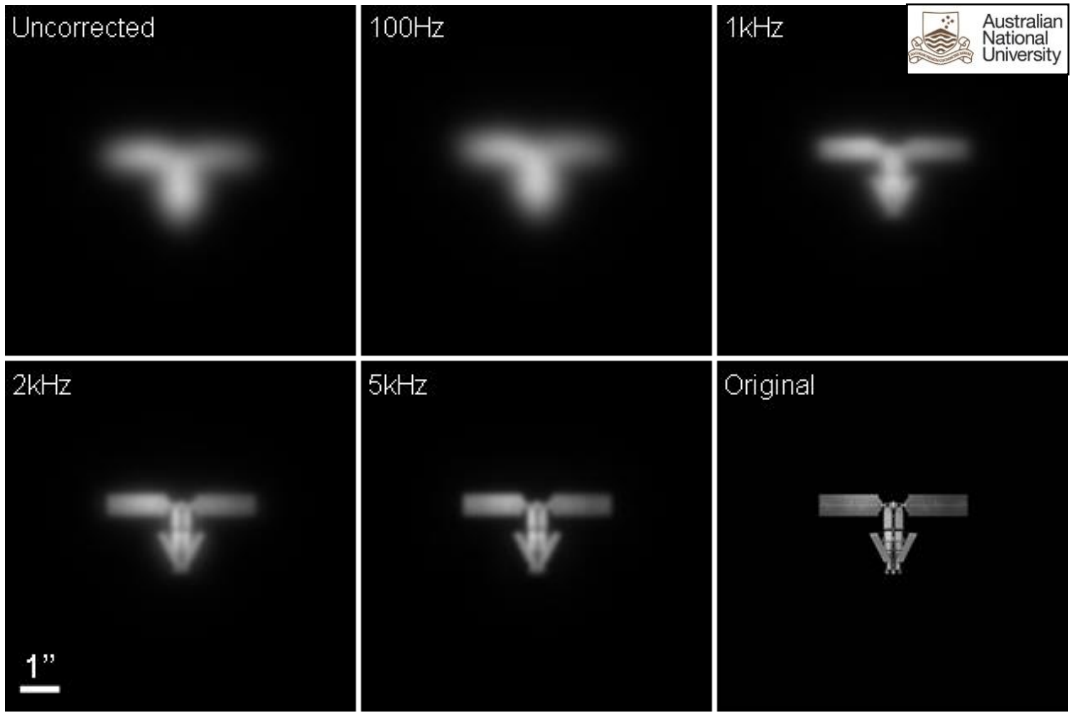
Debris manoeuvre using ground-based laser photon pressure



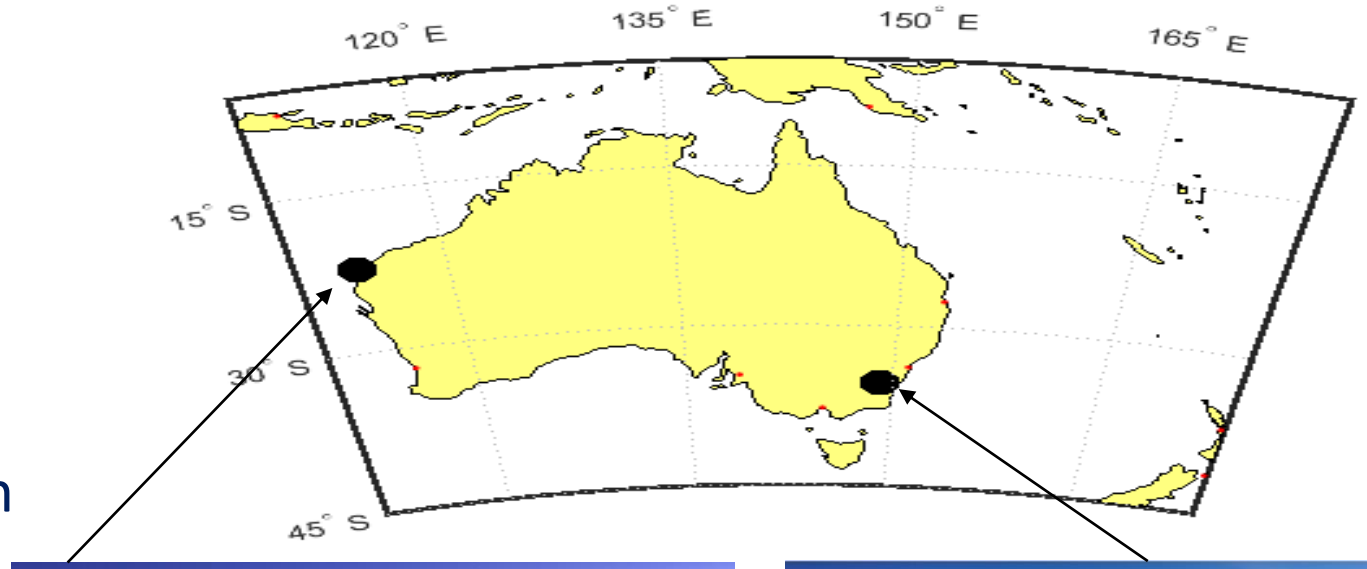
Complicated and challenging program



Iridium satellite @ 1000km

Sensor network

- EOS Space Systems' Space Debris Tracking Station at Mount Stromlo
- New operational site at Learmonth
  - Collaboration between EOS Space Systems & Lockheed Martin with support from AUS DoD



Learmonth, WA (22° S, 114° E)

Mt Stromlo, ACT (35° S, 149° E)

System ID	Site	Aperture	Configuration
A1	Mt Stromlo	1.8 m	Active + Passive
A2	Mt Stromlo	0.7 m	Passive
B1	Learmonth	1.0 m	Active + Passive
B2	Learmonth	1.0 m	Active + Passive
B3	Learmonth	0.7 m	Passive
B4	Learmonth	0.7 m	Passive

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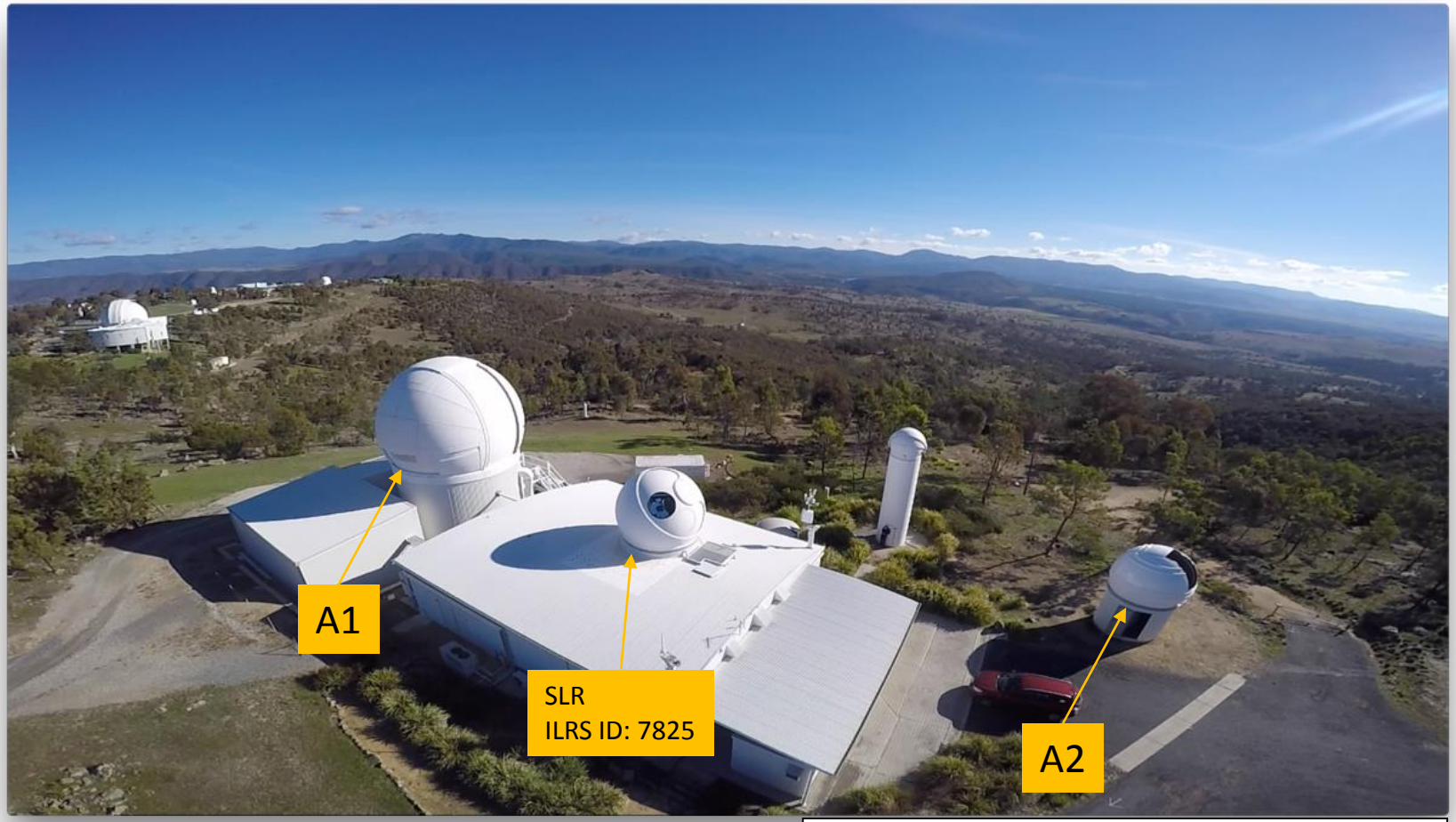
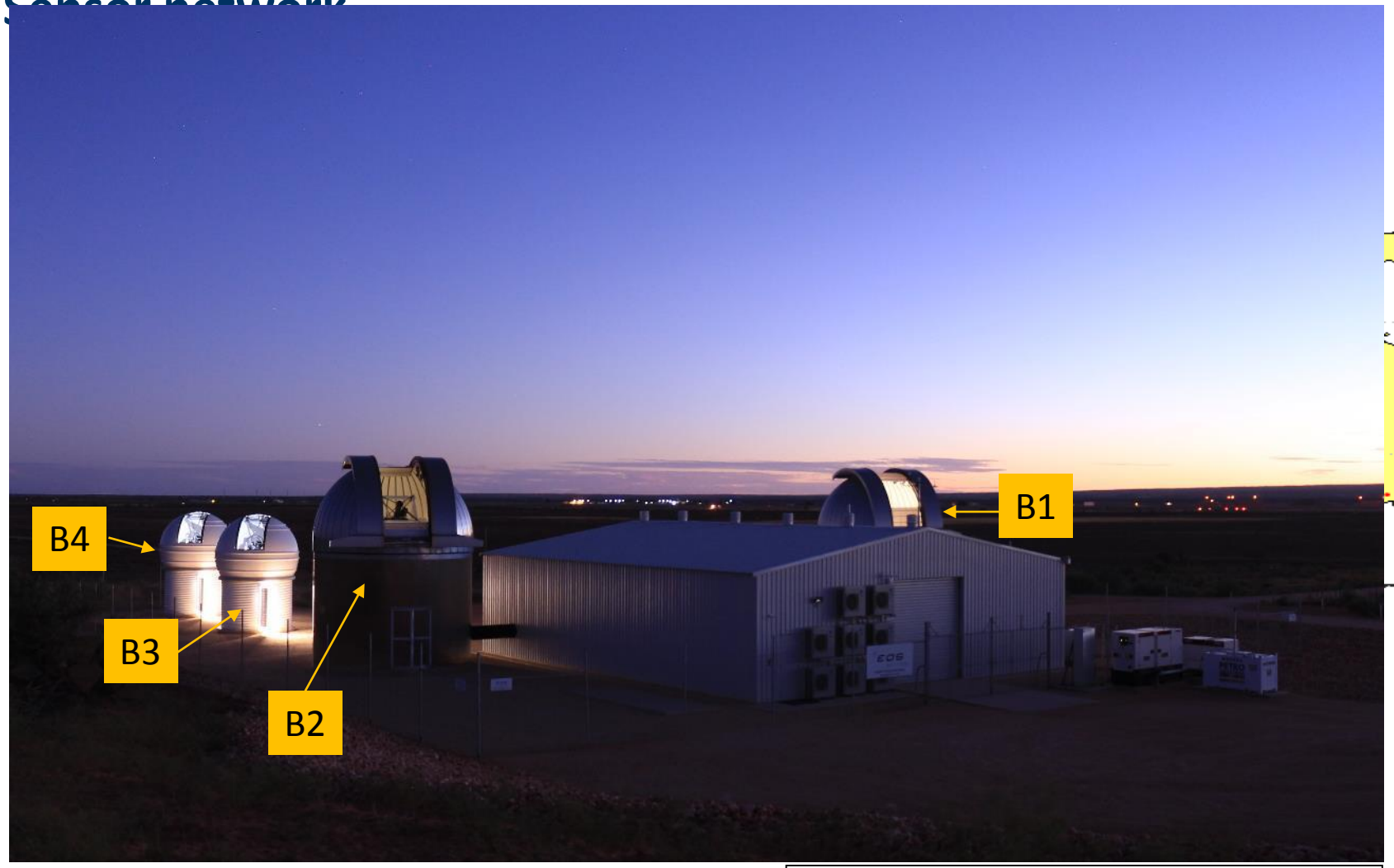
Sensor network – Mt Stromlo

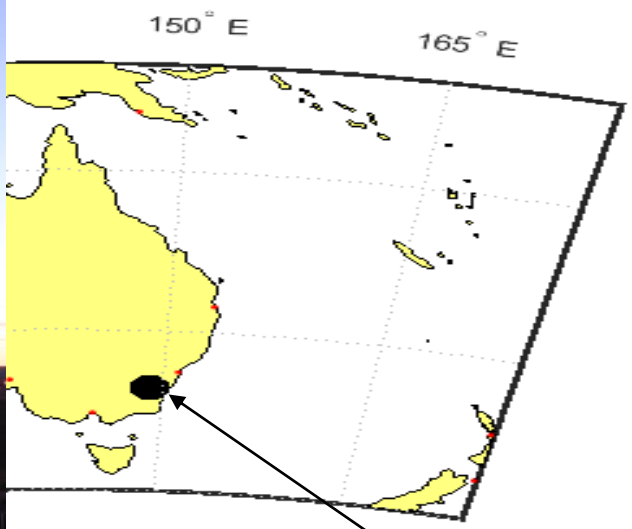


Mt Stromlo, ACT (35° S, 149° E)

Sensor network

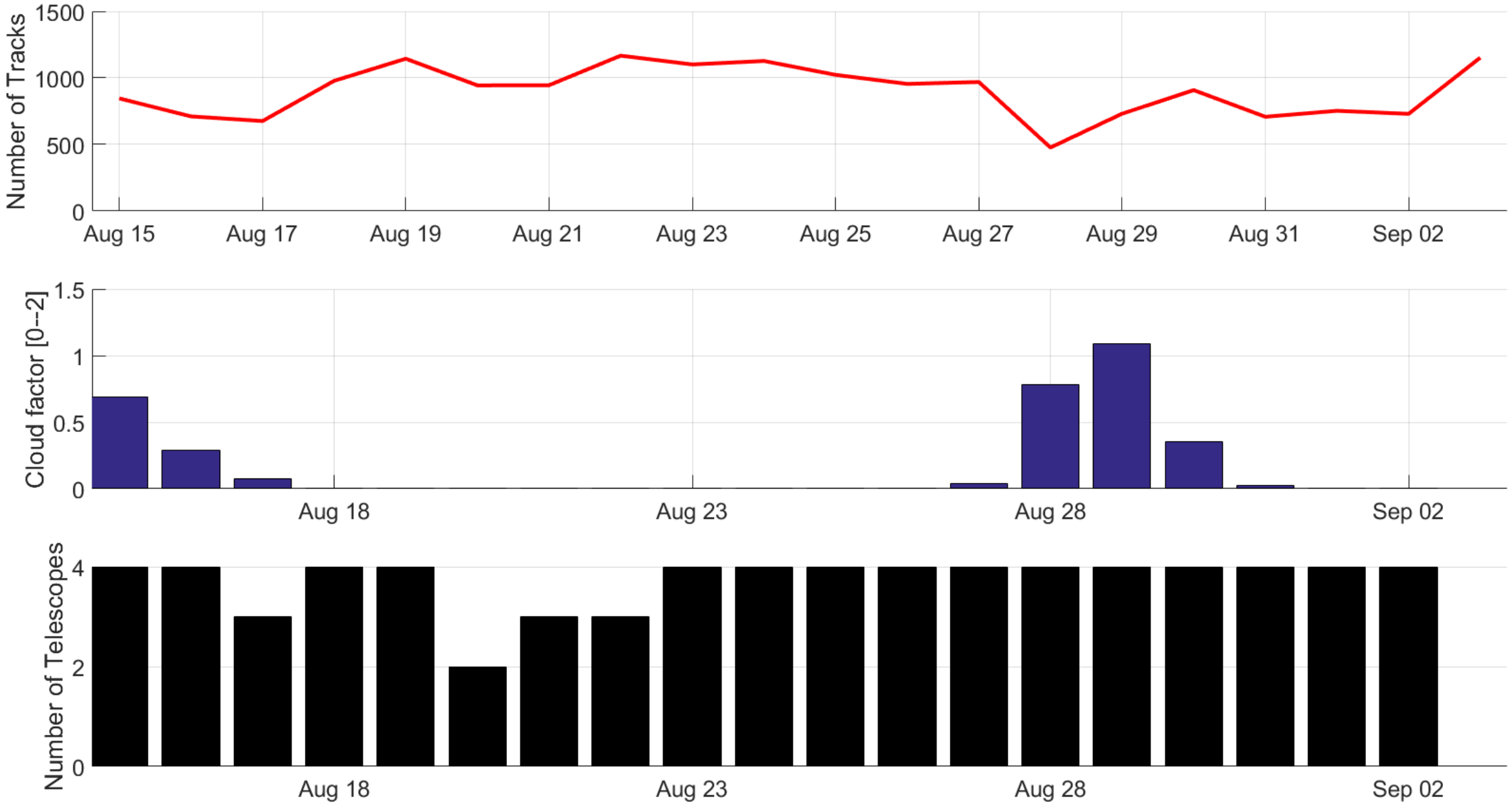


Learmonth, WA (22° S, 114° E)

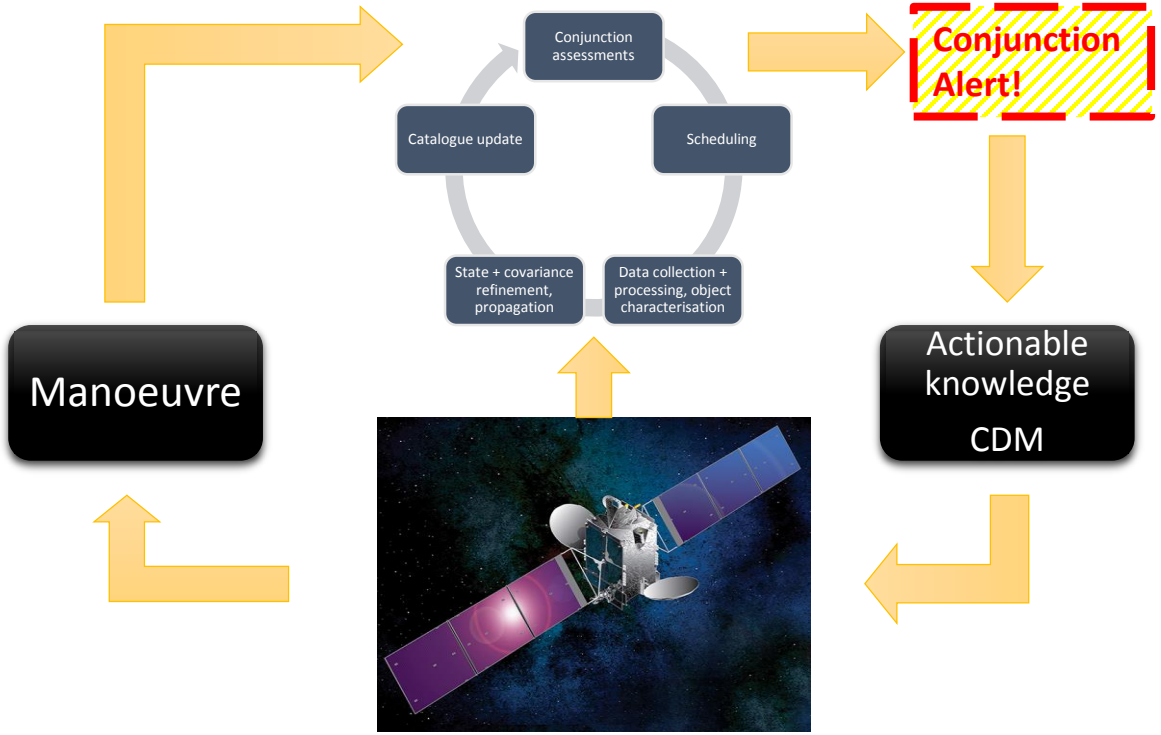


Mt Stromlo, ACT (35° S, 149° E)

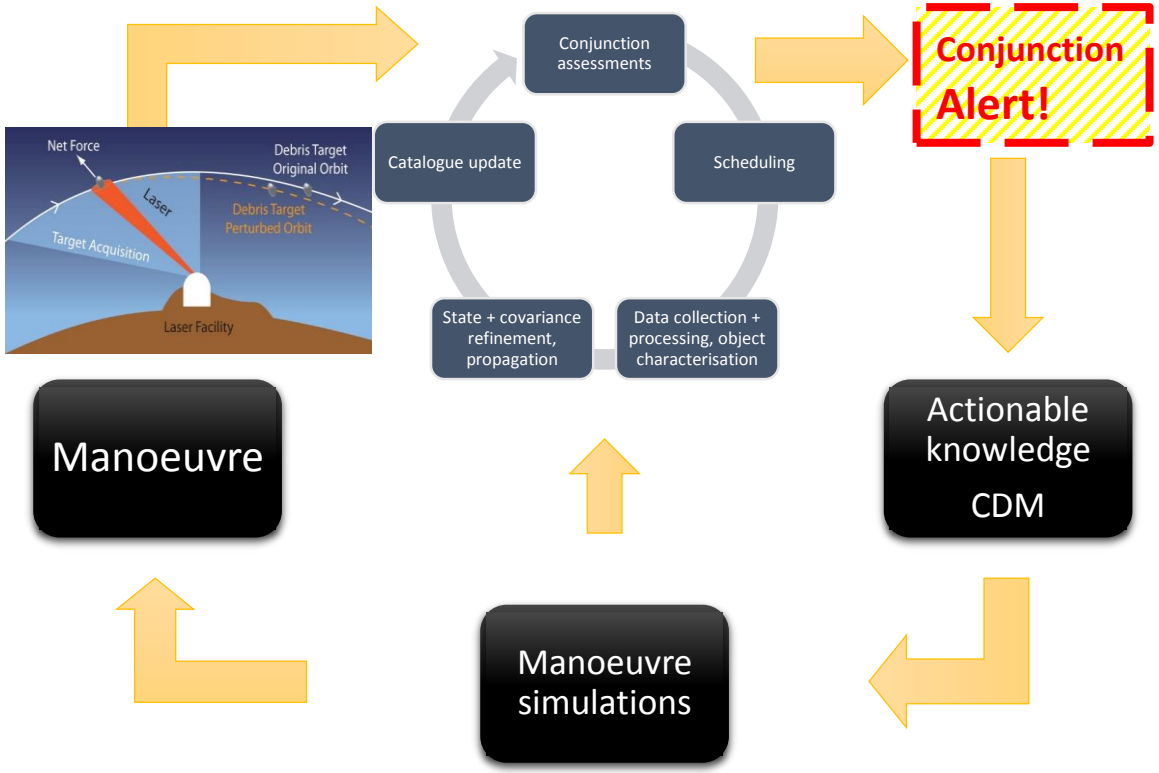
Recent tracking – Learmonth only



Research Program 3: Space Asset Management



Source: https://www.optus.com.au/about/network/satellite/fleet/optus-10



The current Space Asset Management team

Research staff:
- Dr James Bennett
- Dr Daniel Kucharski
- Dr Marek Möckel
- Dr Michael Lachut
- Dr Sven Flegel
- Mr Jeffrey Wardman
- Mr David Kooymans
- EOS Space Systems Team
- Industrial Sciences Group

Satellite operators:
- Optus

PhD Candidates:
- Mr Joseph O'Leary
- Mr Richard Samuel
- Mr James Allworth
- Ms Hansani Kaushalya Perera THANIPPULI KANKANAMALAGE

Student Interns:
- Thomas La
- Nathaniel McGrath

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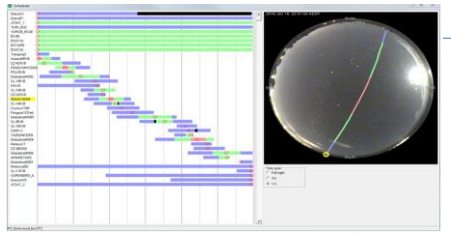
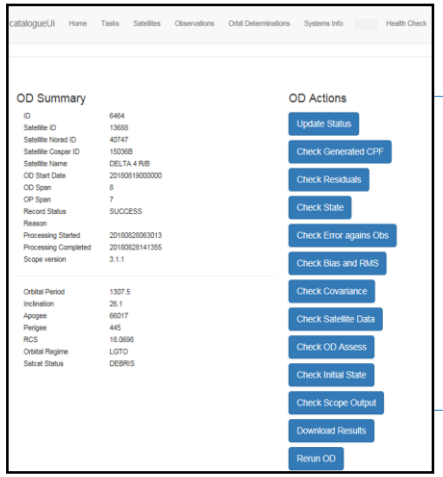
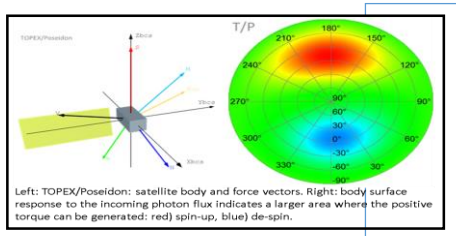
Conjunction and Threat Warning Capability



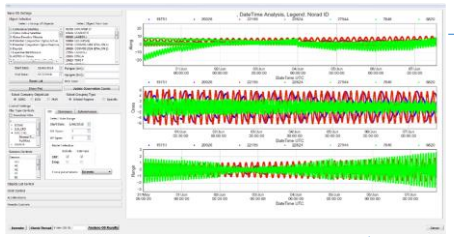
Multi-sensor information gain-based optimised scheduler



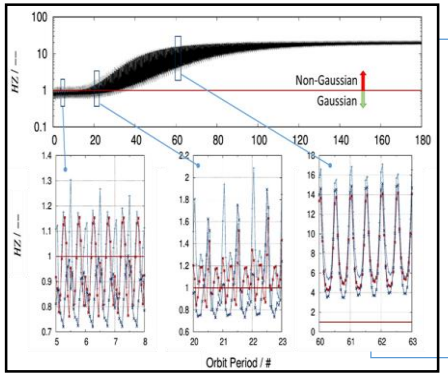
Central database-backed application, HTTP interface with small html frontend, Relational database, Traceability, Automation, System monitoring



Object characterisation for the laser manoeuvre experiment, spin analyses, high rate photon detector, high rate sCMOS camera

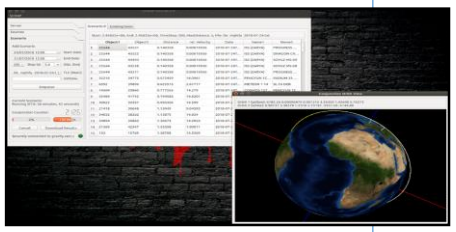


In-house OD software in C++, automated ephemeris generation and sensor cueing, manoeuvre fitting



Rigorous assessment of the breakdown in Gaussianity of the state uncertainty

Probability of collision, actionable knowledge



Parallelised conjunction assessments: CPU & GPU; large speed-ups achieved; generic propagator interface; numerical integration; operator ephemerides (e.g. Optus)

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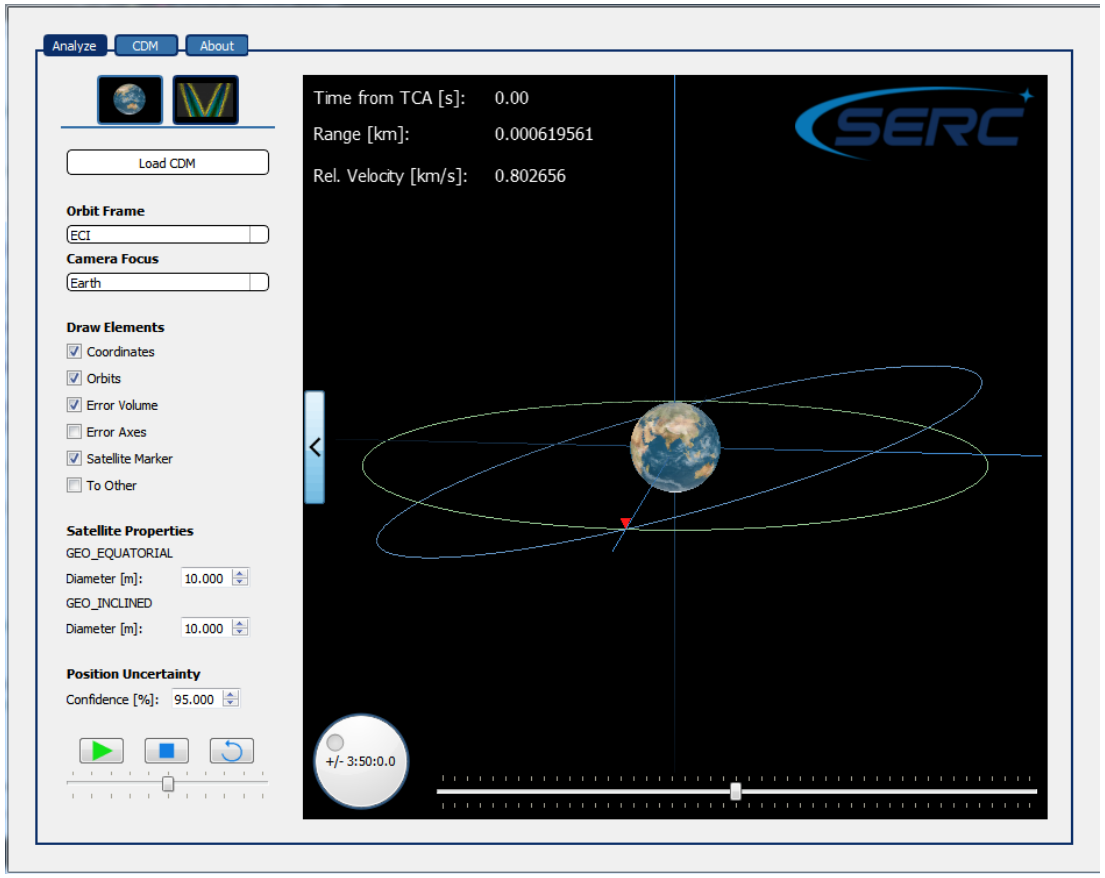
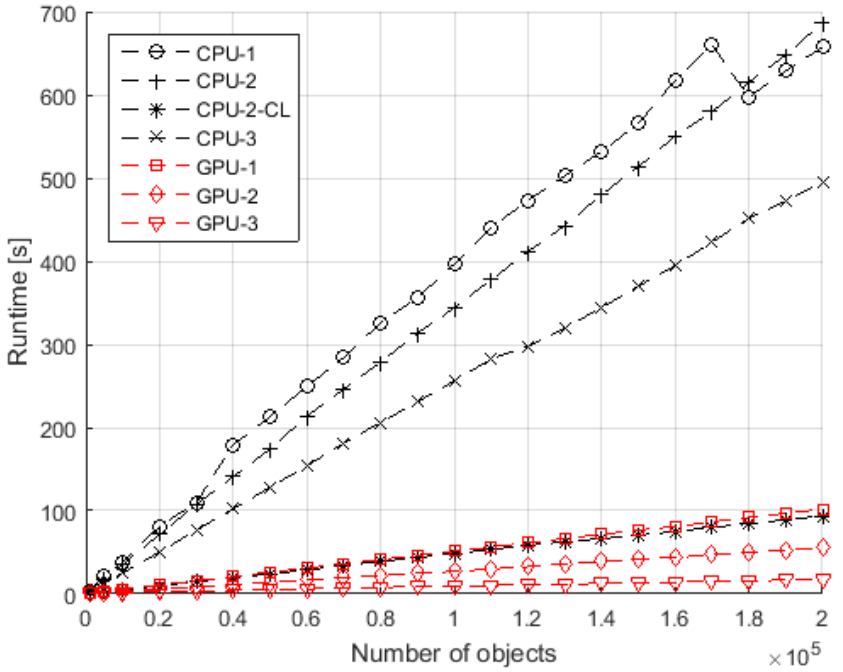
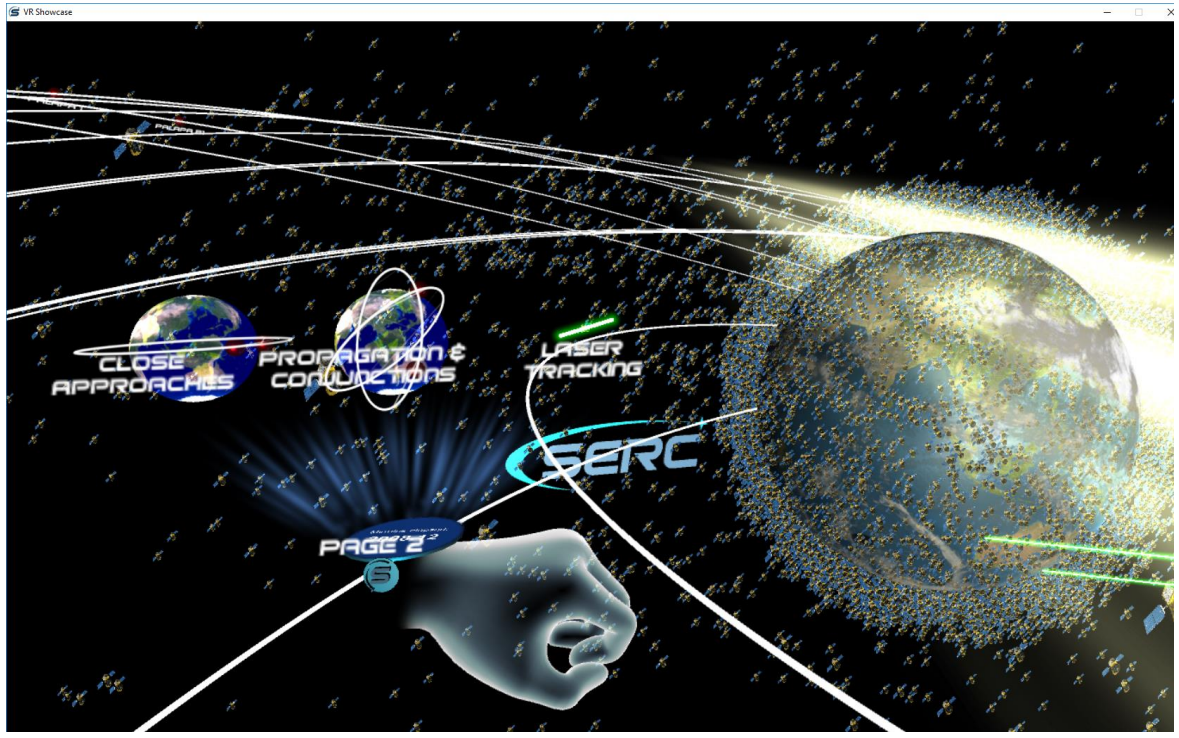
CDM visualisation





CPU-1	Intel i7-4710HQ 3.5GHz (1 core)
CPU-2	Intel Xeon E5-1620 3.6GHz (1 core)
CPU-2-CL	Intel Xeon E5-1620 3.6GHz (OpenCL, 8 cores)
CPU-3	Intel i7-7700 3.6GHz (1 core)
GPU-1	Nvidia GeForce 860m (OpenCL)
GPU-2	Nvidia GeForce GTX960 (OpenCL)
GPU-3	Nvidia GeForce GTX1070 (OpenCL)

Speed tests



Virtual Reality

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Summary

- SERC has significantly increased capabilities in SSA
- Full Conjunction and Threat Warning Service will achieve full operational capability mid 2019
  - Trials with Optus
  - Ready for laser manoeuvre
- On track for laser manoeuvre demonstration in 2019
- SERC MoU with KASI

Memorandum of Understanding

between

KOREA ASTRONOMY AND SPACE SCIENCE INSTITUTE

776 Daedeokdae-ro, Yuseong-gu, Daejeon, 34055, Republic of Korea

and

SPACE ENVIRONMENT RESEARCH CENTRE LIMITED

AITC2 Mount Stromlo Observatory, Cotter Road, Weston Creek, ACT 2611, Australia

Preamble

This Memorandum of Understanding (MOU) has been developed between Korea Astronomy and Space Science Institute ("KASI"), a government-funded research institute for astronomy and space science in the Republic of Korea, and the Space Environment Research Centre Limited, ACT, Australia ("SERC"), a body corporate funded through the Australian Government's Cooperative Research Centre programme. KASI and SERC will be referred to throughout this MOU individually as the "Party" or collectively as the "Parties".

The Parties agree that this MOU is not legally binding, but reflects a spirit of co-operation between them. Any collaborative scientific projects will be subject to more detailed agreements. Each Party will identify collaborative research opportunities of mutual or individual interest, and where there is agreement to proceed, specific contractual arrangements detailing terms and conditions of collaboration will be negotiated between the Parties.

Article 1: Purpose

The purpose of this MOU is to establish a general framework of scientific collaboration in space environment management between the Parties with such collaboration having as its aim to:

- combine expertise to achieve scientific goals;
- develop common specialized knowledge and effective use of facilities; and
- increase co-operation and mutual support.

Article 2: Collaborative Activities

Collaborative activities between the Parties may be implemented through:

- joint meetings;
- exchange of scientific personnel including students; and
- joint research and development.

In particular, the Parties will identify specific subjects for joint research and development which may include:

- orbital dynamics measurement, analysis and modeling of the space objects up to the geostationary altitudes;
- re-entry and de-orbit events observations and analysis;
- conjunction analysis with the special focus on the domestic satellites;
- common experiments on the innovative technology such as multistatic laser ranging, adaptive optical imaging, laser telecommunication; and
- other activities deemed appropriate.

Dr. Inwoo Han
President
Korea Astronomy and Space Science Institute

Date: _____

Article 3: Contact Persons

The Parties will each designate a person who will be responsible for the co-ordination of scientific collaborations arising from this MOU.

Article 4: Scientific Results

The Parties may consider the allocation of rights to any scientific results arising from collaborative activities, including the publication of such results.

Article 5: Costs

Costs relating to collaborative scientific projects under this MOU shall be apportioned by mutual agreement between the Parties, with the Parties exchanging estimates of costs likely to be incurred before such items of expenditure arise, and agreeing on any proposed expenditure to be set out in contractual arrangements.

Article 6: Duration and Amendment

This MOU shall take effect from the date of last signature and shall remain valid until 30 June 2019. Three months before the date of expiration, the Parties shall consult with each other about the extension of this MOU. The Parties may modify this MOU as jointly determined by written agreement. This MOU may be terminated by either Party giving not less than six months written notice to the other party.

Article 7: Confidentiality

Confidential Information of a Party must not be disclosed to any third party without prior written approval of the other Party.

Article 8: Interpretation of Terms

In the event doubts should arise in the interpretation of the provisions of this agreement or problems about matters not described therein, both parties shall consult with each other and settle them amicably in the spirit of this agreement.

IN WITNESS WHEREOF, each of the parties hereto has caused this agreement to be executed in duplicate by its duly authorized officer, and retains one each of the duplicate texts having equal authenticity.

Dr. Ben Gregne
Chief Executive Officer
Space Environment Research Centre Limited

Date: _____

KASI 한국천문연구원 Korea Astronomy & Space Science Institute

SERC SPACE ENVIRONMENT RESEARCH CENTRE

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Thoughts/conclusions

- Sovereign capabilities are needed, as is international cooperation
- Space debris is a global problem, needs a global solution
- Space object tracking infrastructure, controllable
- Space programme continuation: avoid the loss of trained space experts due to gaps in funding
- Enhance sovereign space industry

Questions?

James Bennett

EOS Space Systems / Space Environment Research Centre

Email: jbennett@eosspacesystems.com

SERC SPACE ENVIRONMENT RESEARCH CENTRE

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Australian Government
Department of Industry, Innovation and Science

Business Cooperative Research Centres Program