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Science and Technology Facilities Council

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RASOR: Radio Astronomy and Space Observation Research Facility – A Future Prospect for UK Sovereign Capabilities Across Space Weather, Space Situational Awareness, and Radio Astronomy

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1. Abstract

[1]

RASOR is a potential new facility operating across a wide range of radio frequencies. It would enable unique observational and monitoring capabilities for frontier science across space weather, cosmology, astrophysics, and also in addressing strategic requirements for the prediction of adverse space-weather events and characterisation of assets/debris in orbit. This advancement, when realised, represents a major step-change in current capabilities, addresses up to 13 of the 23 of the UKRI STFC Science Challenges in the UK, strong links into several UN Sustainability Development Goals, and will have substantial near- and long-term direct economic and societal impacts beyond research. It also has the option of being a UK sovereign infrastructure, or with direct links into infrastructures across Europe and further afield.

A fully-implemented RASOR would be a truly multi-disciplinary/interdisciplinary world-class facility on UK soil with UK resilience at its heart. It would be capable of crucial space-satellite/space-debris tracking, space-weather observations across the Sun-Earth chain, and improvements to current UK radio-astronomy capabilities. RASOR would go beyond current and planned capabilities, providing direct access to high-resolution, rapid-response radio imaging and dedicated space-weather monitoring, unavailable anywhere else, and it would also feed into Met Office space-weather monitoring requirements and has potential to feed into the wider space situational awareness needs of the UK's National Space Operations Centre (NSpOC). In addition, if also equipped with a dedicated transmitter, further enhancements in Space Situational/Domain Awareness can be forthcoming. Here, we will provide an overview of RASOR with a focus on space weather and the space environment.

2. What is RASOR?

The Radio Astronomy and Space Observation Research Facility (RASOR) is a concept for a powerful new UK facility for rapid response, high-resolution radio astronomy; space-weather observations and prediction; and with space situational awareness capabilities. It is a multifaceted, multi-frequency, radio-telescope/array with deployments around the UK based on LOFAR and SKA capabilities and hardware (strong heritage).

RASOR can be deployed in one go, or in stages with a semi-modular design in terms of rollout and potential operations…

Strategic fit to the UK's National Space Strategy (2022) and National Security Strategy (2025).

3. RASOR Preliminary Activity (PA)

[2]

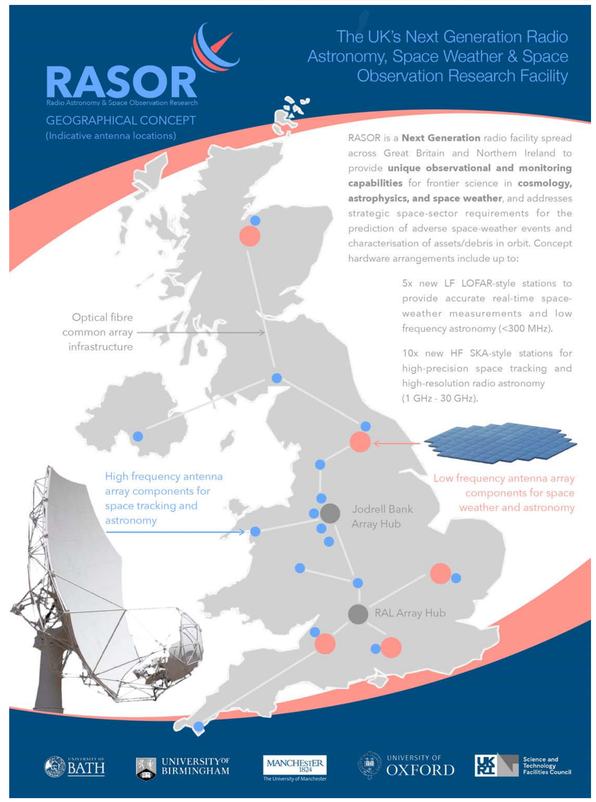
Key Objectives of RASOR-PA (risk reduction):

- Installation and commissioning of a new SKA dish in North Wales; connection to existing e-MERLIN network; demonstration of science results.
- Optimised location design for further ~10 new SKA dishes and ~5 new low-frequency stations balancing science requirements, costs, and local support.
- Design study for UK Space-Weather monitoring/forecasting system using the new array of dishes/antennas.
- Plan for Space Situational Awareness use: analysis of multi-static capabilities/techniques, potential dual-use modalities.
- Fully-costed design and implementation plan plus business case for the RASOR infrastructure roll-out, addressing design/cost risks with formal review by external experts.

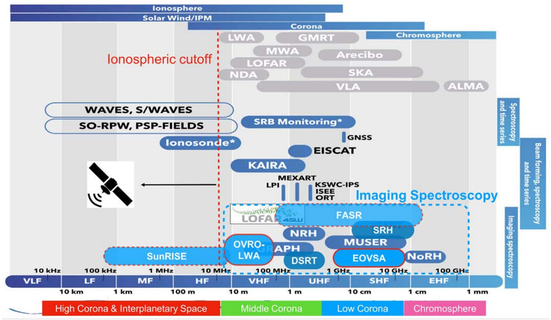
4. RASOR Full Infrastructure

A geographical starting concept of a RASOR Full Infrastructure is shown to the right. RASOR will:

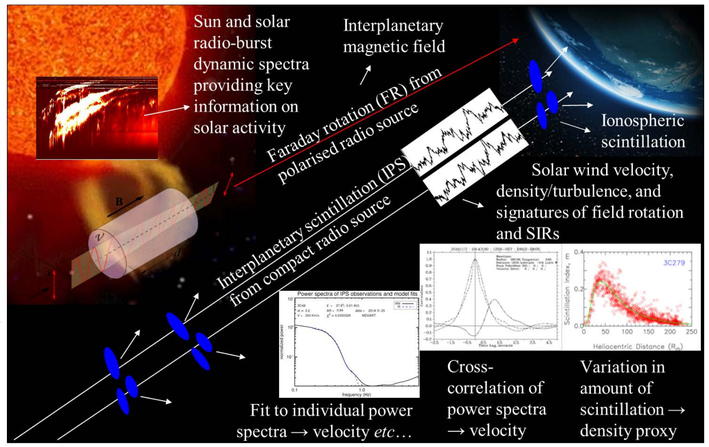
- Provide a world-leading capability enabling a fundamental new understanding of the Earth's space-environment, incorporating critical research into a large strategic project for improved space-weather science and forecasting;
- Provide a timely, low-cost, low-risk route to a UK capability in high-resolution radio imaging to answer frontier questions in cosmology and astrophysics; and
- Provide advances into the SSA/SDA domain.



5. Current Radio Space-Weather/Heliophysics Coverage/Observing… [3]



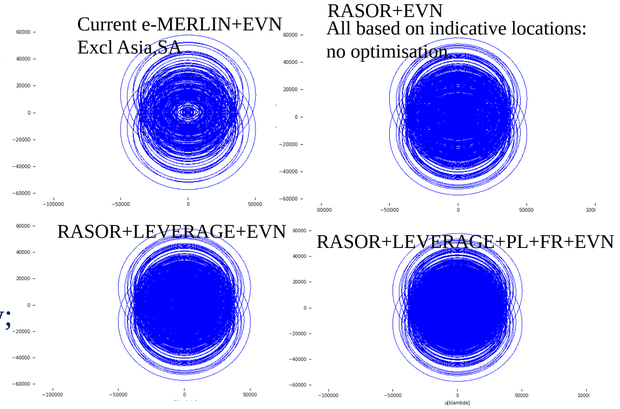
Above: from Carley *et al.*, JSWSC, 2020 and the LOFAR4SW Project; adapted by, and courtesy of, Bin Chen.



6. Radio Astronomy Advances

Can we optimise for European deployments?

- Antenna placement;
- Frequency bands;
- Compatibility; and
- Operations.



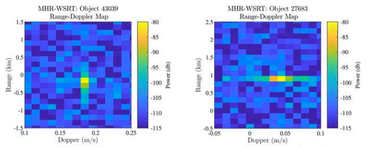
All National/European proposals include EVN augmentation – could have >20 new small dishes in Europe? RASOR would allow for an increased availability/flexibility for EVN with improved uv coverage (see above-right set of images). Adding to existing collaborative capabilities.

7. Space Situational/Domain Awareness (SSA/SDA)

In 2010, NATO declared Space as a new warfighting domain. NATO's Space Policy defines Space Domain Awareness (SDA) as an evolving, shared understanding of "the operational space-related environment, threats and vulnerabilities". Thus, RASOR would also support capabilities, such as Space Situational Awareness (SSA) which is vital for obtaining a space operational picture tying into the linkages with the radio-astronomy techniques and space-weather awareness.

Methods of SDA/SSA observation:

- Electro-Optical (EO) technologies; and
- Radio-Frequency (RF) observing methods.



Doppler measurements (left) are very accurate and reveal that the object has a positive Doppler at the time of the data acquisition.

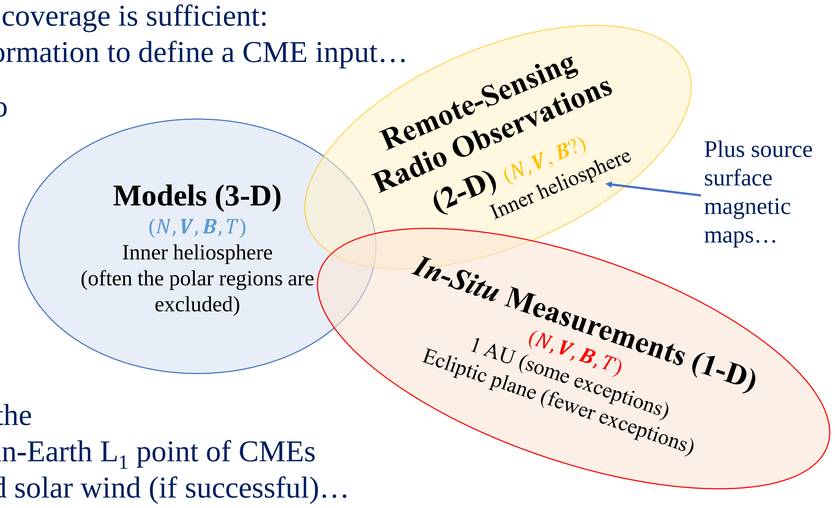
Radar systems, although much more costly than EO systems, are employed for SDA. There are ways in which the costs can be reduced such as: Long baseline bistatic radar (LBBR) and/or Passive Radar; both receiving capabilities would be built into RASOR.

8. Bringing Radio into the Space-Weather Spotlight… [4]

Across the Inner Heliosphere: Radio Data, Models, and Other Data Sets…

ISWAT

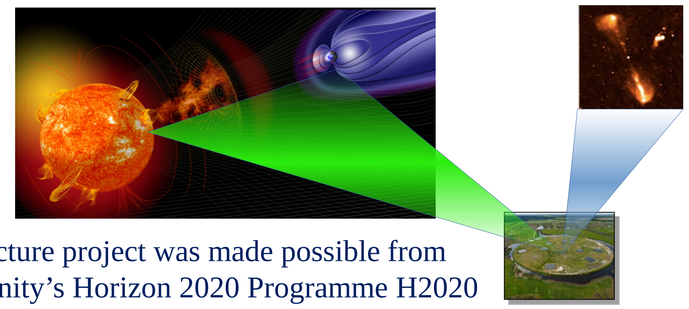
- Radio observations of the heliosphere cover both background solar-wind features and CMEs when the temporal and spatial coverage is sufficient:
  - No need to adding other information to define a CME input…
- More work needs to be done to validate/verify the strengths and uses of radio in the heliospheric domain (see RISER talk in Session 4A on Thursday at 10:30h)…
- Faraday rotation (blue skies) could open the "Holy Grail" of getting to determination of the magnetic field inside of the Sun-Earth L_1 point of CMEs and potentially the background solar wind (if successful)…



9. LOFAR4SW Capabilities…

The key element of the ongoing LOFAR4SW developments is a dual-beamformer for the LOFAR HBA tiles – this is the DANTE project which forms another part of the overall LOFAR2.0 upgrades.

- This will make one telescope into two:
  - With NO effect on normal astronomy operations!
- Critically, RASOR low-frequency arrays will come with the full space-weather capabilities as standard…
  - The LOFAR4SW research infrastructure project was made possible from funding from the European Community's Horizon 2020 Programme H2020 INFRADEV-2017-1 – under grant agreement 777442.



10. RASOR Summary and the Future…

RASOR will provide a sovereign capability on UK soil as a standalone system with science and 24/7 SWx/SSA capabilities allowing for multi-integration options across Europe, and more widely. It builds on strong heritage with unique combinations of low-frequency arrays with high-frequency dishes – thus allowing better simultaneous science and monitoring. It will allow for UK capability/technology developments in receivers and correlators as well as enhanced network connectivity; and is de-risked to a high degree through RASOR-PA. Linkages across many sectors and government departments with large multi-community academia support to date.

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