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## Enhancing Satellite Longevity: Proactive Management and Operational Excellence of RADARSAT-2

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### Abstract

RADARSAT-2, an Earth-Observation mission operated by MDA Space, has surpassed its initial mission design and it continues to deliver excellent performance and quality data after 17 years in orbit. This is a feat made possible by excellence in spacecraft design, as well as the professionalism and expertise of the operations team. This sustained success has been achieved through continuous improvements that have been crucial in maintaining high performance and reliability for the mission. This paper will present an overview of the mission's achievements and major challenges while highlighting the proactive risk management strategies that have been key to sustaining high performance both in orbit and on ground. It will also highlight the critical role of updating and optimizing procedures, as the operations team continues to adhere to certain effective processes from mission inception while adopting other processes when advantageous. As the RADARSAT-2 spacecraft continues operations, the Ground Segment infrastructure also needs to be maintained and upgraded periodically to address issues from aging and obsolescence. A review of the benefits to the mission from proactive maintenance of ground segment infrastructure will be presented. RADARSAT-2's image quality has been maintained at a high level throughout the mission life. Building on this success, several new beam modes have been added at different stages of the mission, including recent experimental beam modes. These advancements are facilitated by effective transfer of knowledge through established procedures.

**Keywords:** Earth observation, satellite mission, risk mitigation, operations management, mission sustainability, lifecycle optimization

### Acronyms/Abbreviations

SAR	Synthetic Aperture Radar
MODEX	Moving Object Detection Experiment
COD	Coarse Orbit Determination
MLI	Multi-Layer Insulation
CDU	Column Drive Unit
TRM	Transmit Receive Module
POD	Precise Orbit Determination
TAS-I	Thales Alenia Space - Italy

## 1. Introduction

Earth-observing satellites play a critical role in scientific research, environmental monitoring, and operational applications. While these missions are typically designed with a finite lifespan, some satellites surpass their initial design life and continue to deliver high-quality data and exceptional performance well beyond expectations. Such longevity is not accidental but rather the result of a combination of robust spacecraft design and the expertise and professionalism of mission operations teams. The RADARSAT-2 mission serves as a remarkable example of this success. Despite the inevitable aging of the spacecraft, it continues to operate at a high level, continuously providing valuable data as it now enters its 17<sup>th</sup> year in orbit. This extraordinary achievement has been made possible through a commitment to operational excellence, proactive management strategies, and continuous improvements that have played a crucial role in sustaining mission performance and reliability. This paper explores the key strategies that have contributed to the extended operational life of the mission; focusing on proactive management techniques, which has extended RADARSAT-2's operational lifespan, while refining its capabilities to better serve customer needs.

## 2. Mission Background

RADARSAT-2, a commercial, high reliability, fully redundant spacecraft, which consists of a Synthetic Aperture Radar (SAR) payload used for Earth Observation, was launched on December 14<sup>th</sup>, 2007, and was commissioned on April 27<sup>th</sup>, 2008. A representation of RADARSAT-2 can be seen in Figure 1. RADARSAT-2 is owned and operated by MDA Space, at the control centre of the Canadian Space Agency in St-Hubert, Quebec. The operational orbit of RADARSAT-2 is near circular and sun-synchronous with an altitude of 798 km, an inclination of 98.58°, with a local time of ascending node at 18:00 hours  $\pm$ 15 minutes. The orbit has a 24-day repeat ground track cycle and is tightly controlled to remain within 150 meters of nominal ground-track at node crossings. RADARSAT-2, originally designed for a 7.25-year mission (7 years of Routine Operations plus an initial 3-month commissioning phase), has significantly exceeded its expected operational lifespan and remains fully functional 17 years after launch. This extended mission duration highlights the robustness of its design, the effectiveness of operational management strategies, and the adaptability of on-board systems. Continued performance assessments show that the satellite remains capable of supporting its mission objectives, providing valuable data well beyond its initial design life. This is indicative by over 1.2 million successfully acquired images over 17 years of routine operations. The success rate of tasked acquisitions has consistently remained above 98%.

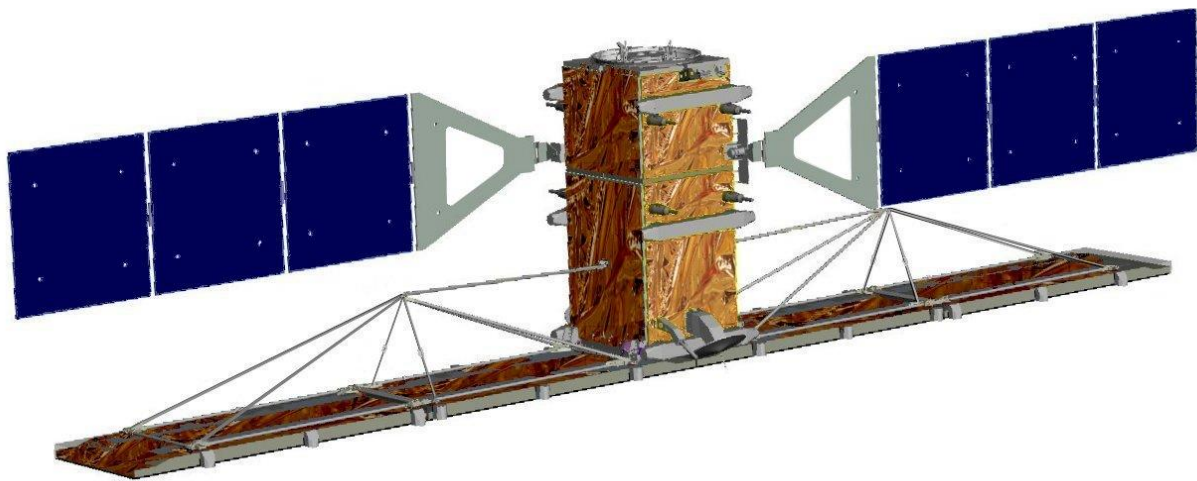


Fig. 1. RADARSAT-2 deployed configuration

## 3. Proactive Management Strategies

The operational approach to the mission has been to be more proactive than reactive; a constant effort is made to improve performance and mitigate risks before they materialize [1]. As a result, several enhancements have been made to both the spacecraft and the ground segment over the years. This paper provides a high-level summary of the state of the RADARSAT-2 mission and spacecraft after 17 years of operation while providing details of three risk mitigation initiatives: GPS Mitigation, payload temperature management, and maintaining ground segment infrastructure.

### 3.1 GPS Mitigation

In May 2023, RADARSAT-2's prime GPS unit, GPS-1, was stuck in reacquisition mode and stopped tracking GPS satellites. This ultimately led to temporary loss of attitude precision, which affected the onboard Precise Orbit Determination (POD). As a result, RADARSAT-2 fell back to its default Coarse Orbit Determination (COD), and as can be seen in Figure 2, errors in positioning offset linearly increase with time, resulting in a temporary degradation of geolocation accuracy for some RADARSAT-2 products. In Figure 2, the 8 km outlier in the along-track offset was caused by doppler ambiguity.

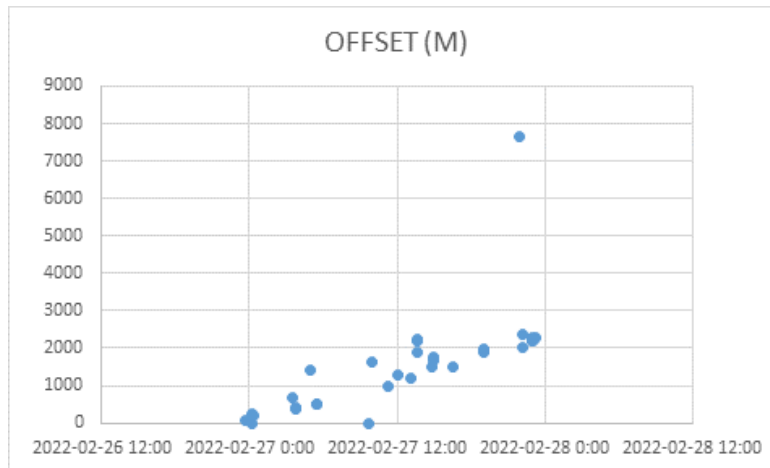


Fig. 2. Impact of location errors during anomaly

Overall, GPS-2 exhibited greater stability and enhanced performance making it the preferred operational unit. Thus, GPS-2 has been in operation since May 4<sup>th</sup>, 2023 and nominal geolocation accuracy was restored for RADARSAT-2 products. At this stage, a decision was made by the RADARSAT-2 operations team to implement proactive measures. This included conducting research and developing a mitigation plan. An assessment was initiated to evaluate the potential impact of simultaneous failure of both GPS units. The solution would make use of range rate data acquired from ground stations to help with orbit prediction and determination (similar to what was done in pre-GPS time such as with RADARSAT-1). The type of accuracy achieved using range rate data is estimated between 30-40m, compared to 10m accuracy when using GPS data. The team is also currently investigating the frequency required for updating the POD and COD vectors on-board RADARSAT-2's in order to reduce attitude propagation errors and subsequently help reduce impact on image quality. The team is also looking into preparing our flight dynamics and planning systems to enable loading POD vectors on a regular basis.

### 3.2 CDU Temperature Mitigation

It is natural for the payload temperature to increase as the spacecraft matures due to the inevitable efficiency losses in the thermal material. Gradual increases of temperature to RADARSAT-2's SAR payload were observed during the first eight years of the mission. The average temperatures of the -X and +X wing of the payload per orbit can be seen in Figure 3. A plot of specific payload components is provided in Figure 4. The plot shows Column-Drive Unit (CDU) 4 and Transmit and Receive Module (TRM) C6R11, which are both the hottest respective components of the hotter (trailing) of the two SAR wings.

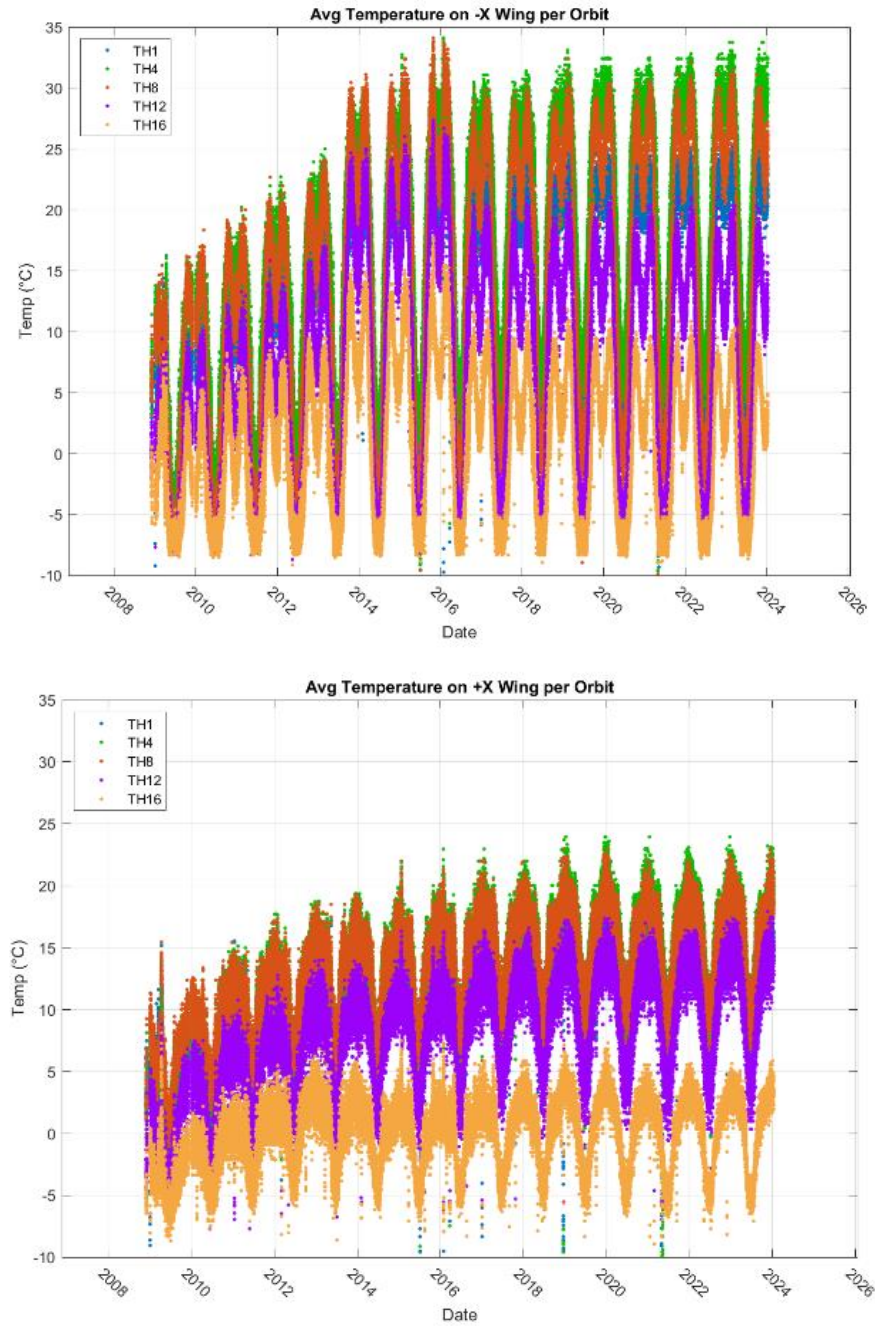


Fig. 3. Payload temperatures over the years on -X and +X Wing

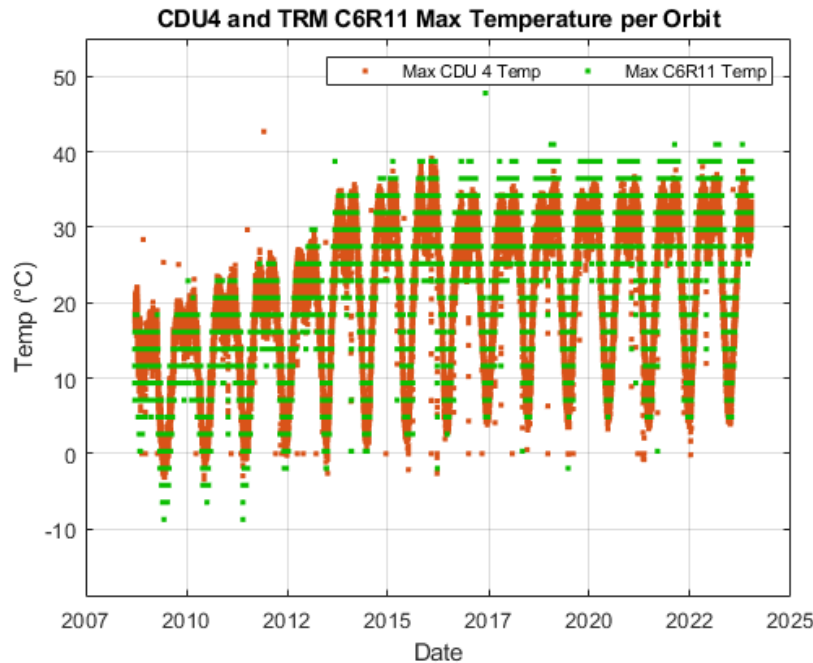


Fig. 4. Max temperatures on -X payload wing for CDU 4 and TRM C6R11

In 2013, a larger increase in temperature was observed due to a change in the solar panel operation. In an attempt to limit the number of charge cycles of the battery, the solar array was put into sun-tracking mode permanently after the end of the eclipse season. Previously, sun-tracking was only used during the eclipse season. By tracking the sun, the solar array can reduce the amount of heat the payload is able to radiate outward, thus increasing its temperature. The alternative is to leave the solar panel at a fixed angle perpendicular to the payload surface (body aligned). In September 2016, automatic sun-tracking of the solar array was disabled outside of the eclipse season and a step reduction in the payload temperature was observed. These can be seen in Figure 3, and the average -X wing temperature in Figure 4.

The maximum operational CDU temperature is 42°C, which was almost reached in 2016. If the warming trend on the payload were to continue after this point, RADARSAT-2 SAR panels would frequently exceed this limit. Putting the solar array in a body-aligned orientation outside of eclipse season successfully reduced the temperature by several degrees. However, to ensure long-term safe operating temperatures, further measures were deemed necessary. The seasonal fluctuations in temperature are caused by the satellite's beta angle, which is the angle between the incoming solar radiation from the sun and the satellite's orbit plane. As a result, RADARSAT-2 experiences two hot season per year from September/October, and January/February. During the months where the temperature peaks, the imaging capacity of the satellite is reduced slightly within the planning system to limit heavy imaging periods onboard the satellite. This is achieved by reducing the payload activity limit by two or four minutes per orbit depending on the time of year. It should be noted that this mostly affects background image acquisitions and has minimal impact on customer imaging.

In 2024, peaks in temperature were observed during the October hot season, as can be seen in Figure 5. As mentioned, the operations team regulates the CDU temperatures by limiting the SAR on time during the hot season to 24 minutes as compared to the nominal maximum SAR on time of 28 minutes. The team has implemented more strategies to help reduce temperature further during the two hot seasons. During this period the imaging limit of background images has been reduced. This is the first time imaging limits to background images has been implemented in operations. The background imaging campaign typically uses high powered beam modes which can also contribute to an increase in antenna temperature. As these images are of the lowest priority, the team decided to limit the amount taken during hot season. It was also observed, as can be seen in the highlighted portions of Figure 5, that the peaks in temperature were also on Friday evenings. The RADARSAT-2 operations team concluded that this coincided with maintenance ground-track burn manoeuvres. During burn manoeuvres, RADARSAT-2's planning system sets the solar panels in sun-tracking instead of body-align for 3-4 orbits, which as previously described increases the payload temperature. A new

strategy was implemented to have the solar panels remain in body-align during burns outside of eclipse season to limit the peaks in temperature during hot season. As can be seen in Figure 6, the new strategy implemented was successful as there were no peaks in temperature in and around burn periods during the January/February hot season. CDU temperatures remained below 37°C. The payload temperature continues to be monitored closely, and further risk mitigation strategies may be implemented if necessary.

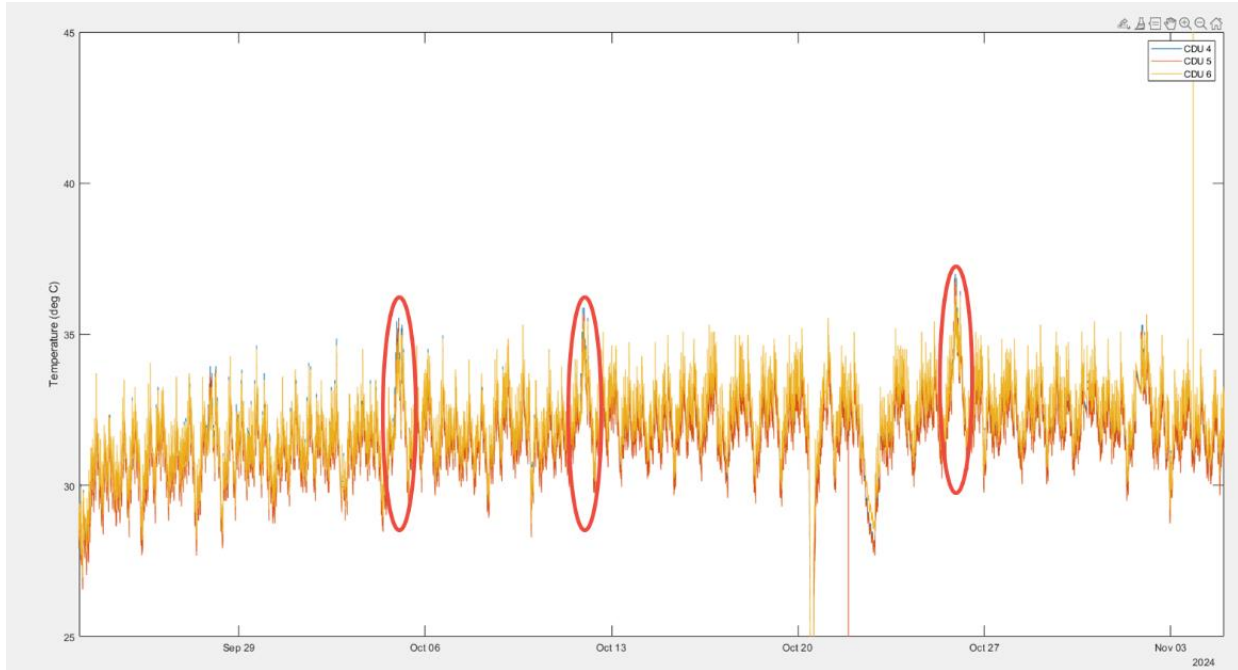


Fig. 5. Payload thermal performance highlighting peaks in temperatures during October 2024 hot season

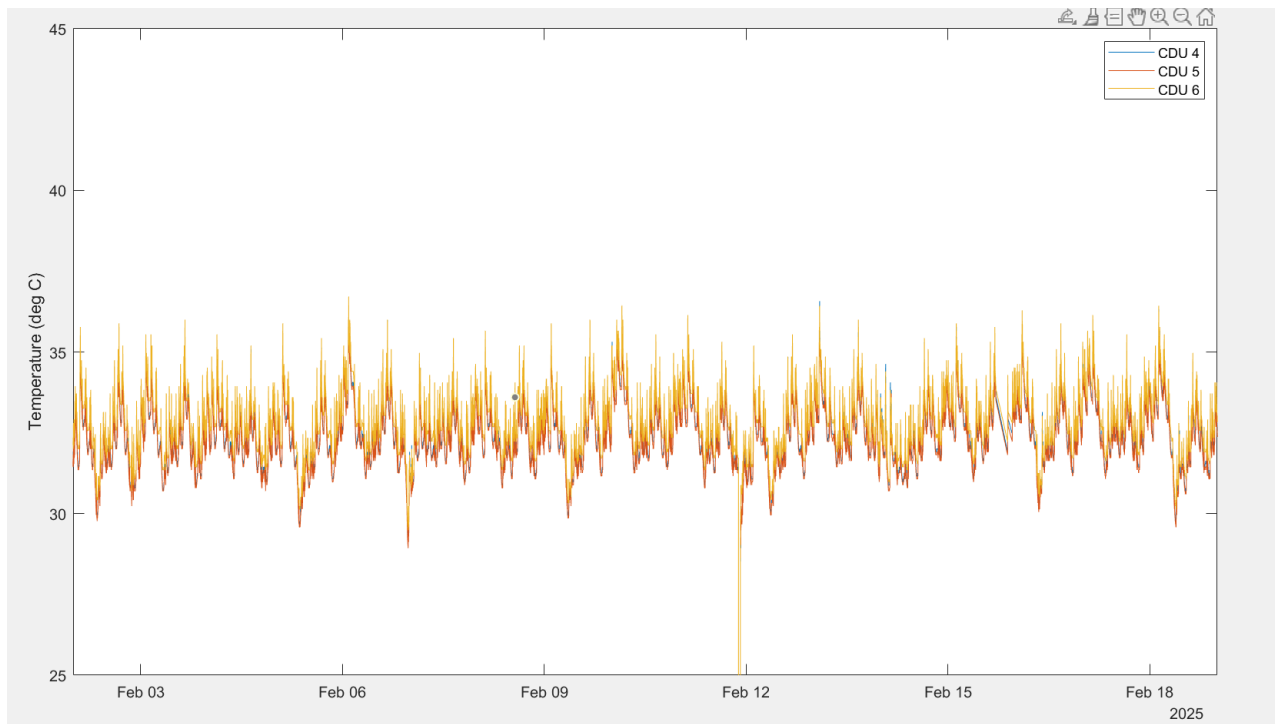


Fig. 6. Payload thermal performance temperatures during February 2025 hot season

### 3.3 Ground segment infrastructure

There have been numerous improvements made to the ground segment during the RADARSAT-2 mission. These changes were not part of the original operations plan because the idea at the time of launch was to use the same ground segment infrastructure for the entirety of the mission life. Two notable changes that have been made during recent years are:

- Virtualization of key ops workstations and servers
- Antenna upgrades

It is unusual for modern computers to be in service for 17+ years, and although there are several in the RADARSAT-2 ground segment that are still functioning well since the launch, most critical systems have been virtualized to ensure sufficient reliability and redundancy. The virtualization effort was started well before workstation failures became a problem, which ensured operational continuity.

Key hardware on the primary ground station used for S-band telecommanding and telemetry, located at the Canadian Space Agency, has been proactively upgraded to ensure smooth and seamless operations for almost two decades. The upgrades include the mechanical steering system, the monitoring and control software, as well as the antenna feed.

### 4. Operational Excellence

Proactive management in RADARSAT-2 operations has been instrumental in achieving operational excellence by optimizing system performance to ensure mission success. With a SAR payload on-board, RADARSAT-2 can provide its customers with reliable, high-resolution imaging that is unaffected by weather or daylight, ensuring continuous data availability [2]. Figure 7 represents the variety of different beam modes that are available from the payload, offering customers several different polarities, swath sizes and resolutions. Many of the beam modes have been added since launch. To maintain high operational standards, RADARSAT-2 operational manual procedures undergo regular reviews and updates based on performance analysis, lessons learned, and evolving mission requirements. Documentation is maintained to ensure clarity, traceability, and adheres to best practices. This allows for seamless knowledge transfer amongst all team members. This structured approach not only ensures the reliability and efficiency of satellite operations, but also reinforces a culture of continuous improvement, ultimately enhancing mission success and customer satisfaction.

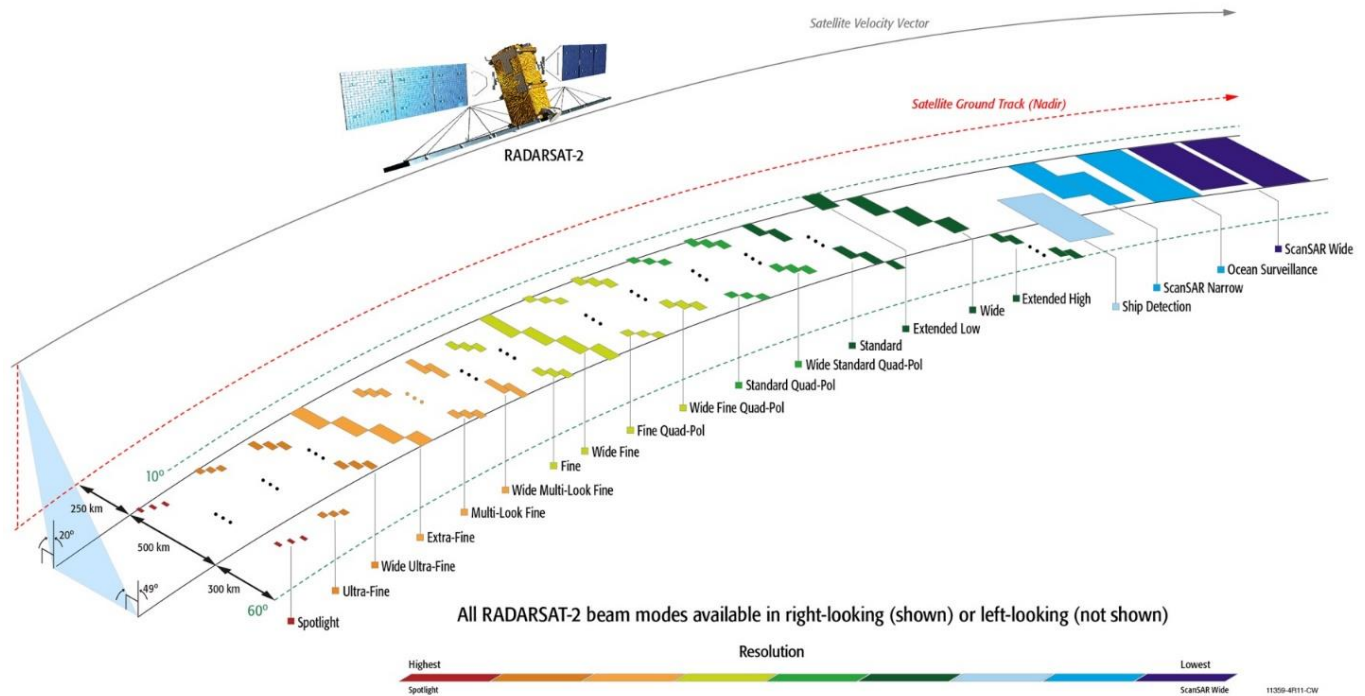


Fig. 7. RADARSAT-2 available beam modes

## 5. Conclusions

The RADARSAT-2 operations team recently celebrated the 17-year milestone since commissioning. The mission has not only exceeded its design and life requirements, but both image quantity and image quality have increased over time and are currently among the highest levels of the mission. The spacecraft has shown very few signs of degradation. Several risk mitigation strategies have been used in recent years to support continued high performance of the mission. These include GPS mitigation, payload temperature mitigation, as well as maintaining the ground infrastructure. The importance of implementing a proactive risk mitigation approach to Operations has been demonstrated numerous times during the RADARSAT-2 mission, and the three examples presented here are a good reminder to continue and possibly redouble these efforts as the Operations team follows the satellite well into its second decade.

## Acknowledgements

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