# OVERVIEW OF NEWSPACE SYNTHETIC APERTURE RADAR INSTRUMENT ACTIVITIES

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## ABSTRACT

This paper reviews the recent activities in the field of NewSpace synthetic aperture radar (SAR) with particular attention to the instrument aspects and serves as the introductory paper of the "NewSpace SAR Instruments" Invited Session of the 42<sup>nd</sup> IEEE International Geoscience and Remote Sensing Symposium (IGARSS).

*Index Terms*— NewSpace, synthetic aperture radar (SAR).

## **1. INTRODUCTION**

The term NewSpace has become very popular in the last decade. Whereas used in different contexts and with sometimes contradictory meanings, it refers to the pursuit of common, nongovernmental market goals bounded primarily by market forces, executing activities in an entrepreneurial way in contraposition to the pursuit of goals set by governments, with boundaries defined by political and social forces, executing activities that tend to be risk averse, based primarily on public financing, and generating competenceenhancing, sustaining innovations [1]. Numerous commercial actors have entered the NewSpace business, raising funds to launch constellations of small satellites (smallsats) for connectivity and remote sensing, including synthetic aperture radar (SAR) [2].

NewSpace SAR instruments have been launched by a number of private ventures from three different continents. The proposed solutions show a high degree of innovation in technology, processes, and mission operations. The instruments are much cheaper than in conventional, "OldSpace" SAR missions and still allow for good imaging performance.

This paper reviews the recent NewSpace SAR activities, from the missions to the cost reduction drivers and the instrument concepts, and serves as the introductory paper of the "NewSpace SAR Instruments" Invited Session of the

IEEE International Geoscience and Remote Sensing Symposium (IGARSS). A session on the same topic was successfully organized also in the previous edition of the symposium [3].

#### 2. FIRST NEWSPACE SAR MISSIONS IN ORBIT

The first NewSpace SAR system is recognized to be the X1 demonstrator of the Finnish company ICEYE, launched on January 12<sup>th</sup>, 2018 by an ISRO PSLV-C40 rocket and delivering its first image three days later. The peculiar characteristic of this satellite is its overall mass of only 85 kg, which makes it belonging to the category of the microsatellites (mass below 100 kg) [4]. As a term of comparison, the TerraSAR-X satellite weights 1230 kg.

After ICEYE, which has in the meanwhile launched a total of 14 SAR microsatellites, further companies, among which SSTL (UK), iQPS (Japan), Capella Space (USA), Synspective (Japan), Spacety (China) also had at least a SAR satellite in orbit by the end of 2020 [3]. According to the website NewSpace Index, which provides updated information about the launched and planned NewSpace satellites, four more companies have launched SAR satellites in 2021 and many more launches are planned for the upcoming years [5].

The total funds raised for NewSpace SAR satellites are already in the order of half a billion U.S. dollars and destined to further increase with a significant impact on the Earth Observation data market.

#### **3. PECULIARITIES OF NEWSPACE SAR MISSIONS**

The main peculiarity of NewSpace system is definitely the drastic cost reduction. A single NewSpace SAR satellite typically costs less than \$15M, whereas traditional SAR missions are characterized by costs at least one order of magnitude higher [6]. NewSpace SAR systems are not always characterized by the capabilities and the flexibility of traditional SAR systems, still the significant cost reduction

allows for launching constellations of numerous satellites with advantages related to e.g., rapid revisit.

The aforementioned cost reduction has been achieved through three main drivers:

- 1) An innovation in the instrument design;
- 2) The use of Commercial Off-the-Shelf (COTS) components;
- 3) A new instrument development and integration approach.

The instrument design is driven by the cost, i.e., NewSpace SAR instruments are conceived to provide the best achievable performance for a given cost. This turns into a reduction of the number of distinct acquisition modes, with impact on instrument commanding, operation, test, verification, validation and calibration.

As for the use of COTS components, while already adopted sometimes even in space in the past, NewSpace systems employ them largely and even to perform tasks considered as critical. The components are carefully selected, looking at their space heritage, and tested.

Finally, the vertical integration of the instrument, based on in-house development of main components, hardware and software, reduces dependencies from third parties and therefore costs.

## 4. INSTRUMENT CONCEPTS

Table 1 summarizes the most important characteristics of some in-orbit NewSpace SAR instrument concepts.

Instrument	Mass [kg]	Frequency band	Antenna size [m]	Peak power [kW]	Acquisition mode(s)	Resolution (range[m]×azimuth[m])	Swath width [km]
ICEYE-X1	85	Х	3.2×0.2	4	Strip	10×10	80
ICEYE- X2-6	85	Х	3.2×0.4	4	Strip Spot	3×3 1×1	30 5
SSTL NovaSAR- 1	400	S	3×1	1.8	Strip Scan	6×6 20×20	20 100
Capella-2	107	Х	ø3.2	0.6	Strip Spot	2×2 0.5×0.5	5 5
Synspective Strix-α	130	Х	4.9×0.7	1.6	Strip Spot	3×3 1×1	10 10
Spacety Hisea-1	185	С	N/A	N/A	Strip Spot	3×3 1×1	N/A N/A
iQPS Izanagi	100	Х	ø3.2	N/A	Spot	1×1	N/A

**Table 1.** Most important characteristics of some in-orbitNewSpace SAR instrument concepts.

A variety of implementations can be observed with frequency bands ranging from S to X band. For the X-band instruments the total satellite mass is comprised between 85 and 130 kg. Higher masses characterize the C-band Spacety's and the S-band SSTL's satellites. Both planar phased-array-based and reflector-based antennas are used. In particular, Capella Space's instrument with its 3.2 m reflector also allows a significant reduction of the peak power (600 W) compared to traditional satellites.

NewSpace SAR missions mostly aim at high or very-high, sub-meter resolutions over narrow swaths/specific areas, therefore exploiting the stripmap and/or spotlight acquisition modes. Both Capella Space and ICEYE have recently show the ability to map areas of 5 km  $\times$  5 km with resolution of 30 cm  $\times$  25 cm and 25 cm  $\times$  25 cm, respectively [7]-[8]. Furthermore, ICEYE has an experimental mode able to map a spot of 25 km  $\times$  25 km with resolution of 1 m  $\times$  1 m [8].

While the very limited orbital duty cycle does not make those missions suitable for continuous global coverage as traditional satellites (e.g., Sentinel-1). The availability of constellations, however, offers incredible opportunities for rapid access and persistent monitoring over selected areas.

An exception is represented by the S-band NovaSAR-1 SAR system of SSTL, which is able to cover in ScanSAR mode a 100-km wide swath and even a 400-km wide swath using its maritime mode (not reported in Table 1) [9].

## 5. RESEARCH ON NEWSPACE SAR

According to the definition provided in the introduction NewSpace is primarily related to private initiatives, still several research institutions and universities see a great potential of NewSpace for SAR and have started addressing research in this direction. Moreover, some disruptive SAR imaging techniques provide a significant improvement of the SAR imaging performance with only minor impact on system complexity and costs.

As far as the exploitation of smallsats for SAR is concerned, the Microwaves and Radar Institute of the German Aerospace Center (DLR) has recently proposed the concept of an "ambiguous" high-resolution wide-swath lowpower SAR for ship monitoring and of two "ambiguous" modes for high-resolution wide-swath SAR, which do not require digital beamforming and can boost the capabilities of conventional SAR systems [10]-[12].

Further opportunities arise from the exploitation of swarms of formation-flying satellites [13-16]. Here we find concepts based on alternate transmission [13], simultaneous transmission over the full bandwidth [14], or simultaneous transmission using different sub-bands [15].

As for the instrument simplification, a technique to get rid of the nadir returns using waveform diversity and a postprocessing step, developed at DLR and recently demonstrated using the TerraSAR-X satellite, is an appealing option to remove a relevant constraint in the SAR system design [17]-[19]. This technique has also been recently adopted by ICEYE [8].

#### 6. CONCLUSION AND OUTLOOK

Current, planned, and future NewSpace SAR systems represent a huge opportunity for Earth Observation. They should not be seen only a replacement of traditional SAR systems, but also and especially as a complement that can enormously enhance the capabilities of SAR remote sensing.

One of open challenges for the future is the design and development of NewSpace SAR systems for single-pass interferometry and tomography.

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