GOSA – AN OFFSHORE SPACEPORT FOR MIRCOLAUNCHERS

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Germany profits from the boom of the New Space movement, a growing number of start-ups and small and medium-sized companies offering space-based solutions stimulates the space industry in Germany. With HyImpulse, ISAR Aerospace and Rocket Factory Augsburg, three promising European Microlauncher companies are located in Germany. A German spaceport enabling launch of small satellites to Polar or Sun Synchronous Low Earth Orbits provides the opportunity for this growing New Space location to develop a cluster in a future market and thereby create an economic eco system, which spans everything from the manufacturer of the smallest screw to the complete application of the product. Bremen as the German "City of Space" is the perfect host for the Spaceport: In Bremen's aerospace sector, more than 140 companies and 20 institutes with around 12,000 employees generate over 4 billion euros per year. In 2020, the companies Tractebel DOC Offshore, MediaMobil, OHB and Harren & Partner joined their forces in the German Offshore Spaceport Alliance on the basis of their unique competencies in their respective fields of activity in maritime offshore and space projects. The concept foresees a preparation area in Bremerhaven, Germany, and a mobile launch and control infrastructure on two vessels. The fully integrated launcher is transported to the launch site in the offshore German exclusive economic zone (EEZ) where the launcher is erected and prepared for a launch. The infrastructure and the operational concept is kept flexible and agile to be able to serve different type of launchers and to offer rapid turnaround between two launches. The project has the ambitious target to be ready in 2023 to offer launch possibilities for the European and international microlauncher provider to serve the worldwide growing small satellite market. In September 2021, the German Offshore Spaceport Alliance GOSA signed MoUs with Skyrora, Rocket Factory Augsburg, T-Minus and HyImpulse. This paper will give an overview on the infrastructure and the operational concept, it will cover topics like airspace and maritime safety and it will show the recent progress in the implementation of the German Offshore Spaceport with regard to technical aspects.

1 INTRODUCTION

Over 100 microlauncher projects and initiatives have been announced worldwide since the 2000s. Although most of them are located in the United States and China, Europe's share of the current boom in small launch vehicles cannot be neglected. In Germany, the space start-up scene has recently been the focus of attention, not only with new satellite providers and downstream application start-ups but also with new microlauncher companies. A mobile offshore launch platform in the North Sea will give the German economy the chance to participate as best as possible in the boom in the space industry.

The German initiative for the Commercial Space Transportation Services and Support (C-STS) launcher program of the European Space Agency (ESA) has clearly shown that the German government is adopting a dual and market-oriented approach in setting its priorities. The German funds subscribed in the program are converted directly into start-up orders, which replace the prize money for microlauncher in a German competition. Germany has thus created a competition to promote three competing companies in Germany and at the same time is setting a pioneering brand towards more competition in the overall ESA system.

Other countries are taking other approaches to incentivize microlauncher firms: Public Development Organizations across the continent are keen to attract start-ups from the New Space segment in order to take advantage of the socio-economic benefits associated with the potential launch location. Examples of this are the Highlands and Islands Enterprise (HIE) in Scotland, which promotes the region for launch vehicle operators and supports the construction of a launch site in the Sutherland region. Other launch locations are being developed in Sweden, Norway and Portugal (Azores). Such projects are often supported by a set of rules in order to make the location attractive for start-up service providers.

Based on these considerations, the Federation of German Industries (BDI) asked the federal government in 2018 to check whether a launch site for small launch vehicles in Germany would be feasible. The proposal for a mobile offshore launch platform developed from the BDI initiative, with which launches from the German Exclusive Economic Zone (EEZ) should be offered from 2023 [1], [3]. In December 2020, the operator consortium German Offshore Spaceport Alliance (GOSA) based in Bremen was founded for this purpose.

The industrial partners that joined their forces in the GOSA are Tractebel DOC Offshore, Media Mobil, OHB and Harren&Partner. Tractebel DOC Offshore offers a large expertise in the planning, implementation and operation of maritime offshore projects such as offshore wind parks or submarine energy cable connections. MediaMobil offers communication solution via satellite especially for maritime mobile systems. OHB is a space company with the knowledge of manufacturing and launching satellites. Harren & Partner is a Bremen-based shipping group that has a fleet of 85 units and an expertise in conducting worldwide special projects.

2 ADRESSED MARKET, ORBIT AND LAUNCH LOCATION

The consideration of possible and suitable launch sites for microlaunchers cannot be done without classifying the payloads of the rockets. The European spaceport in French Guiana will retain its strategic importance for European Ariane and Vega rockets due to its location near the equator to reach geostationary (GEO) and medium-altitude (MEO) orbits. The conditions in Kourou are also good for launches in low orbits (LEO), especially for launches in lower inclinations.

With a launch at the Earth's equator, the Earth's rotation does support the satellite launcher to achieve orbital velocity if the launch is conducted in East direction. This “free” velocity thus allows the launch provider to save propellant respectively to transport more payload to orbit. It is dependent on the distance to the earth's axis and therefore largest at the equator.

Microlaunchers that are under development in Europe do have payload capacities up to ~1 ton and are usually interesting for customers with small satellites with a mass of less than 500 kilograms. The small satellites are often categorized in Mini-, Micro- and Cubesat. Different definitions do exist. The following table give one possible categorization, where the Microsatellites are dominated by Earth Observation and the Minisatellites are represented by SatCom applications.

Table 1. Small Satellite Categories

Category	Mass (kg)
Mini-Satellites II	300 - 500
Mini-Satellites I	140 - < 300
Micro-Satellites II	60 - <140
Micro-Satellites I	25 - < 60
Cube-Satellites	1 - <25

The number of small satellites that have been launched in recent years has increased steadily and recently by leaps and bounds. In 2020, despite the pandemic, over 1,200 satellites (including the Starlink satellite network) were launched worldwide, of which only 85 satellites had a mass of larger than 500 kilograms. In a study by Euroconsult [4], 12,510 satellites are expected to be launched in the 2020-2029 decade, around 90 percent will be small satellites and 27 percent microsatellites with a mass of less than 50 kilograms. The annual satellite launches are dominated by the commercial constellations in the near-earth orbits LEO and MEO, such as Starlink and OneWeb. Many of these constellation satellites will be transported to orbit with large launchers and are not easily accessible for microlaunchers. In the same time the number of satellites in the LEO that are not part of a mega-constellation is also increasing. So due to batch launches and regional restrictions the total number of satellites that can be accessible for launches by microlaunchers in Europe is expected to be that around 25 % of the total number satellites launched in this decade.

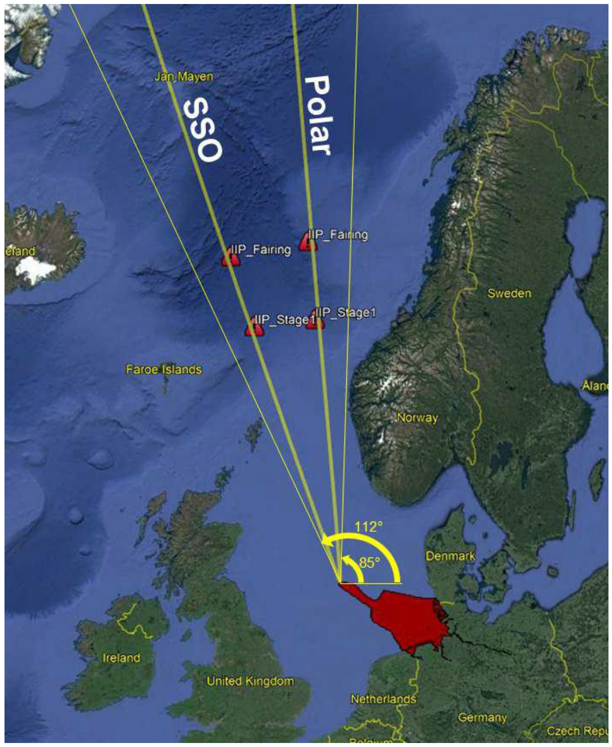

Figure 1. Trajectory corridor of the planned offshore spaceport with a launch site in the German Exclusive Economic Zone (EEZ) [1]

Many of the telecommunication constellations are launched in orbits with an inclination between 40 and 60 degrees in order to cover the mainly populated areas. Other constellations such as OneWeb and Iridium Next have a polar orbit with an inclination of almost 90 degrees.
The Sun Synchronous Orbit (SSO) is a very special orbit for Earth observation satellites, as their orbital plane experiences the same change in rotation as the Earth. As a result, the orbital plane has a fixed angle to the imaginary line between the earth and the sun. The orbital plane of the satellite revolves around the earth once every year. The satellite always flies over a point on the planet at the same time. Due to the constant local time of the overflight, the observations from different days can be compared with each other. Due to the similar angle of incidence (change only due to the position of the sun, which is influenced by the seasons), the reflections of the sun's rays are hardly changed. The satellite: Local Time of Ascending Node (LTAN) determines the local time of the overflight.
A special sun-synchronous orbit that plays an important role in Earth observation is the dusk-dawn-orbit. This name is given to orbits in which the satellite moves on an orbit above the twilight zone, i.e. the transition from day to night on earth. The LTAN for these satellite orbits is around 9:00. The length of the shadow can derived in optical data can be used to determine the height of objects.

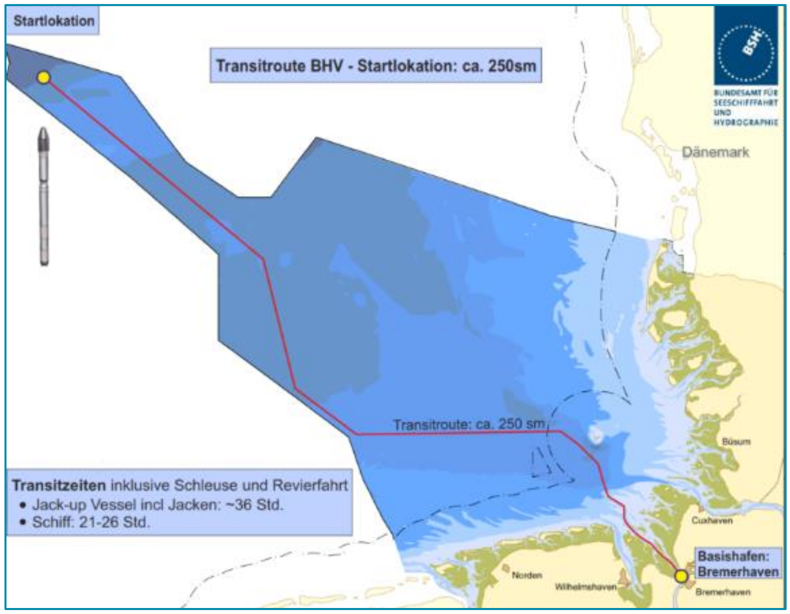

Figure 2. German Exclusive Economic Zone in the North Sea

A location northwest of the Dogger Bank in the North Sea was determined for a rocket launch from the German EEZ, in the so-called “Entenschnabel (engl.: duck's bill)”. The transfer of the platform from Bremerhaven to the launch site takes about one day. The preliminary assessment of the trajectories shows that both polar and sun-synchronous orbits can be reached from the launch location. Flight paths in an azimuth corridor of around 112° to 85° are possible without trajectories over an inhabited area. This suits ~65% of the small satellite customers.

3 Launch Vessel & Launch Box

A key element of the offshore spaceport is the launch vessel. It must meet the requirements of the various microlaunchers and provide the necessary security and stabilization systems.
In the case of the proposal for an offshore spaceport in the German EEZ, the likely solution is a versatile dock vessel equipped with a stern ramp for rolling cargo on and off the vessel and three heavy lift cranes with a combined lifting capacity of 700 tons. The vessel has a high level of stability and can travel with an open hold and an open stern ramp.
The selected transport and launch vessel for the GOSA project is the Combi Dock I. It is the first in a series of four vessels that were built between 2008 and 2010 at the Lloyd shipyard in Bremerhaven.

Fig. 3. Combi Dock RoRo Vessel, possible also to use as Flo Flo cargo transport (e.g. sailing ship)

The construction of the dock vessel allows heavy units up to a weight of several thousand tons to be rolled over the stern ramp onto the main deck instead of being lifted using heavy-duty cranes as is usual. The full launcher is loaded horizontally into the launch box after the satellite has been integrated, which take place in an assembly hall at Bremerhaven. This is an essential point for the implementation of the GOSA concept, as the ro-ro (roll on, roll off) procedure is much faster and safer for the launcher and its payload. The launch box contains all the systems that are important for the launch.

Combi-Dock Vessel Data:

- Stern-Ramp for Rolling Cargo
- 3 Heavy lift cranes, combined lifting capacity of 700 tons
- Length: ~170 m
- Breadth: 25 m
- Cargo Width: 18 m
- Depth 16 m
- Design Draught: 5.6 m
- Velocity: 16 kn
- Loading of heavy units of several 1000 tons over the stern ramp possible

The vessel Combi Dock I is already equipped for the transport of dangerous cargo (International Maritime Code for Dangerous Goods, IMDG). It is also equipped with a recessed locking system to secure the launch box in its intended stowage position.

4 ONSHORE SET-UP & CAMPAIGN

Bremerhaven with its already well established logistic infrastructure for heavy loads and special goods provides an optimal base port and assembly location that reduces the logistics effort for customers from Germany and Central Europe. An existing maritime industry is specialized to supply all kinds of industrial goods (e.g. industrial gases) and services necessary for marine operations. Several transport connections such as highway, railway and maritime waterways guarantee accessibility for all kinds of normal and special cargo to mobilization port Bremerhaven. In addition, the base port is in reachable distance from various North German airports.

Figure 3. Bremerhaven ABC-Peninsula

Foreseen as integration area is the ABC Peninsula that has in total a size of 10 ha (which are not completely needed for the spaceport). The pier offers space for two shipping berths.

Figure 4. Loading of the Mobile Launch Box in Roll-in-Roll-Out procedure

The requirements for the various launcher types and its different types of fuel will be managed by interchangeable container tank elements. The fully integrated Mobile Launch Box containing the microlauncher is rolled onto the vessel and secured on deck for sea transport and the subsequent take-off. The vessel will transit approx. 1 day to the coordinates of the launch location in the outer north-western edge of the German EEZ.

5 MARITIME SET-UP & OFFSHORE LAUNCH

The Mobile Launch Box is seafastened and weather protected during transport by the side wall and the rear ramp. After final preparations and fuelling the roof of the Mobile Launch Box will be opened and the micro-launcher will be erected in launch position. Prior refuelling process, the launch team and the ship's crew will leave the Launch Vessel and the launch control is transferred to a nearby control vessel within a safe distance from which the launch procedure will be remotely continued.

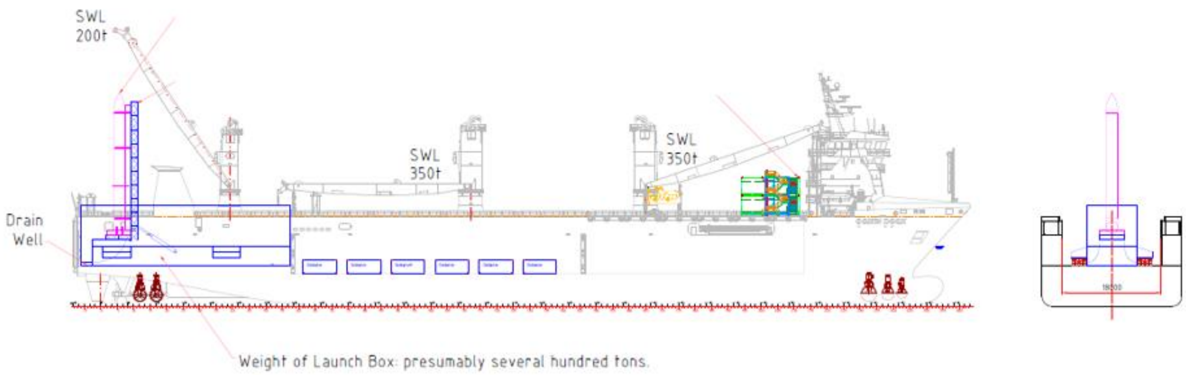

Figure 5. Section view on Vessel and Launch Box during launch

In order to keep the vessel in a defined position, it is equipped with a dynamic positioning system (DP2). High demands on exact positioning and minimized movement during the launch will require a remote control of the vessel in order to meet the requirements of a rocket launch (higher level of redundancy, i.e. higher security in the event of failure of subsystems). The DP2 system together with a remote control will ensure high demands on exact positioning and thus an angle of encounter with the prevailing waves in order to keep vessel movements, in particular pitching and rolling movements, as low as possible.

Before the rocket is launched, the stern ramp of the launch vessel will be opened so that the exhaust jet of the rocket, deflected by a deflector, can exit the vessel unhindered (comparable to the jet funnel on the launch pad).

Next to the launch and the control vessel which are mandatory for the safety of the marine and launch crew as well as for the control of the vessel and microlauncher during fuelling, launch and initial flight phase other supporting units may be required. Smaller guard vessel for the area safety at sea might be required as well as recovery units in case recovery of rocket parts like payload fairings and stages is mandatory. In addition, the offshore concept also offers a good starting point for future developments towards reusable rocket stages and parts that usually return above water for reasons of cost and safety.

Figure 6. Offshore Launch

6 COMMUNICATION INFRASTRUCTURE

The information exchange and communications between the parties involved in the offshore launch activities require an advanced communications infrastructure. This applies to the onshore integration site, the offshore launch area as well as the transit route of the launch vessel and other supporting vessels.

The key requirements for the GOSA information exchange and communications are security, reliability and Quality-of-Service (QoS). Security implies that the users must be authenticated, any network connection must be protected against interception and the integrity of the information content must be ensured. Besides of applying the relevant Cyber Security standards like IEC 62443 and the BZI IT protection directives, network technologies with inherent security features have been selected at the core of the GOSA communications infrastructure. Reliability means that the communications must be always on with very high availability level, especially for the link to the launch vessel when the vessel is evacuated during the actual launch. The GOSA communications architecture is therefore based on a hybrid, fully redundant network concept. QoS flow control mechanisms will ensure that all information and sensor data is classified with different priorities and committed information rates (CIR) to minimize latency and to ensure the performance of the applications.

The network concept is based on the new 5G standard both for the onshore site and for the offshore launch area. The offshore 5G cell will be connected to the onshore network via satellite. Satellite connections will also be used as backup and during the transit of the vessels between the onshore and offshore working areas. Advanced 5G mechanisms like network slices, user authentication, encryption and traffic flow QoS control will be deployed to achieve the requirements described above. The overlay satellite network will be integrated with the 5G infrastructure and will be based on an advanced VSAT platform operated by GOSA.
This is a highly innovative network design which will overcome the limitations of current satellite and cellular networks. It will ensure high performance seamless communications between all parties anywhere anytime during the launch activities

7 FLIGHT & GROUND SAFETY

Air & Sea Traffic is one of the important topics of the future for all European launch sites. With increasing launches worldwide initiatives worldwide want to optimize flight safety with respect safety and economic interests of ships and aircrafts.

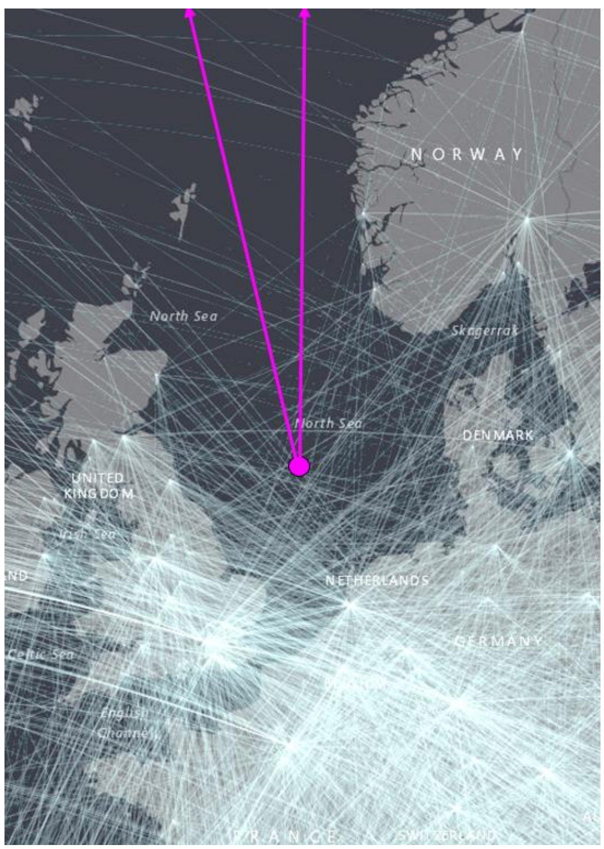

Figure 7. Flight Trajectory

In general, the coordination with sea and air traffic is mandatory like for rocket launches from onshore facilities. The advantages starting from the German EEZ is the avoidance from any inhabited area but still in a central position in Europe. Nevertheless, the launch location at the selected position within the north- west corner of German EEZ and launch direction to the north has the advantages of low traffic volume and low number of fixed sea and air traffic routes. Main

sea routes between the European trade harbours are located east and further south of launch location. Same is applicable for the air routes connecting European most frequented airports.
At sea notification process will be followed to provide sufficient warnings to all seafarers as well as guard vessels will be used to ensure a minimum safety area at sea without any vessels disturbing the launch process.
Flight safety will need coordination and administration of launch permit for upper airspace supported by EUROCONTROL.

ECONOMICAL & ENVIRONMENTAL ADVANTAGES The German offshore spaceport aims to provide an agile and flexible launch solutions for small launchers. In line with the new space mindest, we focus on a low-cost structure. Our concepts benefits from combining existing know-how from different industries and thereby building on existing procedures and infrastructures. We are for instance not building a new ship. The core of our apporach will be the individual, ship-independent "launch box concept". That enables us to basically use very ship in the world. That gives us a high redundancy in the event of ship failure and also a high flexibilily in order to increase the capacities when needed.
Theoffshore spaceport with Bremerhaven as selected base port for the main activities is providing cost advantages compared to other launch sites in Europe mainly due to significant reduction of supply chain costs and higher degree of flexibility for direct support of the launch campaign. This leads automatically to the advantages of improved CO2 footprint.
Due to the fact that the vessel does not have direct interaction with the seabed the launch campaigns from vessel do not imply higher environmental risks than starting from shore.
Customers will benefit from positive influence on the entire CO2 footprint through shorter distances for transport and the reuse of existing infrastructure.
Critical payload characterized by export restrictions and national interest of European governments can be handled and launched avoiding excessive and restricted process of export control. Therefore, time consuming and costly export permission can be avoided which mitigates risk of significant delay within the project schedule.

8 OUTLOOK

The launch site in the North Sea is ideal to serve the growing and urgent need for launch sites for the European institutional payloads, also and above all if the basic idea of a pro-competitive policy is to be taken into account. An offshore spaceport in the European Union offers the launch from EU territory for its own space programs (Galileo, Copernicus or the announced Secure Space-Based Connectivity System). A German spaceport in the North Sea would therefore not compete with the European spaceport in French Guiana, but would complement it sensibly and be available to all partners for their own launches.
Recently the GOSA has signed MoUs with launcher companies such as HyImpulse, Rocket Factory, Skyrora and T-Minus. In a next step the GOSA partner companies will work on a feasibility study to investigate technical, economical and approval-related topics in more detail.

9 ACRONYMS / ABBREVATIONS

BDI	Bund der Deutschen Industrie
BSI	Bundesamt für Sicherheit in der Informationstechnik
CIR	Committed Information Rates

CO2	Carbon Dioxide
C-STS	Commercial Space Transportation Services and Support
EEZ	Exclusive Economic Zone
ESA	European Space Agency
EU	European Union
GEO	Geostationary Earth Orbit
GOSA	German Offshore Spaceport Alliance
HIE	Highlands and Islands Entreprise
IEC	International Electrotechnical Commision
IMCDG	International Maritime Code for Dangerous Goods
LEO	Low Earth Orbit
LTAN	Local Time of Ascending Node
MEO	Medium Earth Orbit
SSO	Sun Synchronous Orbit
QoS	Quality-of-Service
VSAT	Very Small Aperture Terminal

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