



AN ALTERNATIVE DELIVERY OF GNSS AUGMENTATION SERVICES USING LEO SATELLITE CONSTELLATIONS

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GNSS AUGMENTATION

What do we mean by GNSS Augmentation?



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North California

London

Data is uploaded to **C-Nav[®] LEO**
cloud-based virtual processing centers in
two geographical locations

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INDUSTRY GUIDELINES

What are the current industry guidelines for use of GNSS
Augmentation?



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Current Guidelines

Guidelines for GNSS Positioning in the Oil and Gas Industry

IMCA S 015 / IOGP 373-19 – February 2021

It is recommended that at least two **fully independent** positioning systems are installed and available. (4.1.4)

When considering **redundancy** of systems installed, the following should be considered:

- Redundancy of hardware (including spares): Typical installations will require that a minimum of two **independent** satellite positioning systems are installed.
- **Redundancy of augmentation delivery links:** Most installations can provide redundancy in the data link used. Separate and individual data links may offer some protection from interference or atmospheric conditions. Often the selection of a different data link introduces the option of also selecting a different positioning technique;
- **Redundancy of positioning methods:** Two or more independent systems provide the potential for different algorithms and techniques to be used.

Current Guidelines

Guidelines for GNSS Positioning in the Oil and Gas Industry

IMCA S 015 / IOGP 373-19 – February 2021

Operational Awareness (4.5)

- Loss of correction data – Ensure redundant and **diverse** correction links

Risk Management (4.5.2)

Item	Comment	Risk		Possible Mitigation Measures
		Possibility of Occurrence	Severity	
Communication Satellite	Some service providers offer (on a commercial basis) a choice of broadcast satellites or a 'back-up' satellite covering the same world region.	Low	High	<ul style="list-style-type: none">• Use a different satellite data link• Use a different data link technology

Current Guidelines

MTS DP Vessel Design Philosophy Guidelines

(Rev2 – Apr21)

Satellite Based Systems

-Each system should have double redundancy in the differential signal reception system as follows; two different satellite systems, for example, Inmarsat and Spot Beam and two different radio systems with distinct frequencies and redundant transmitter stations with range covering the whole operational scenario of the unit (i.e. DP drillship or DP semi), for example, IALA, MF and UHF.
- Spot beam and Inmarsat both may be transmitted via Inmarsat satellites. Designs should provide for two separate satellite correction data links.

Current Guidelines

DNV Recommended Practice DNV-RP-E306

(Amended October 2021)

Satellite Based Systems

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- Spot beam and Inmarsat both may be transmitted via Inmarsat satellites. Designs should provide for two separate satellite correction data links..... Reception of such correction data links via Inmarsat communications does not provide enhanced reliability or redundancy

LEO vs Geo

What are the differences between a LEO and Geo constellation?



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A yellow Iridium satellite with long solar panel arms is shown in orbit above the Earth's horizon. A thin white line connects the satellite to the text '780 km'.

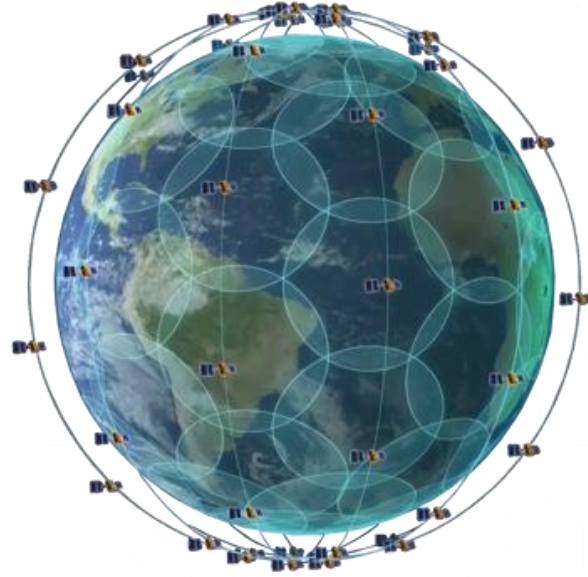
780 km

Iridium Low Earth Orbit (LEO) satellites orbit **780 km** from Earth. Providing strong signals and faster connections for C-Nav[®] LEO end users

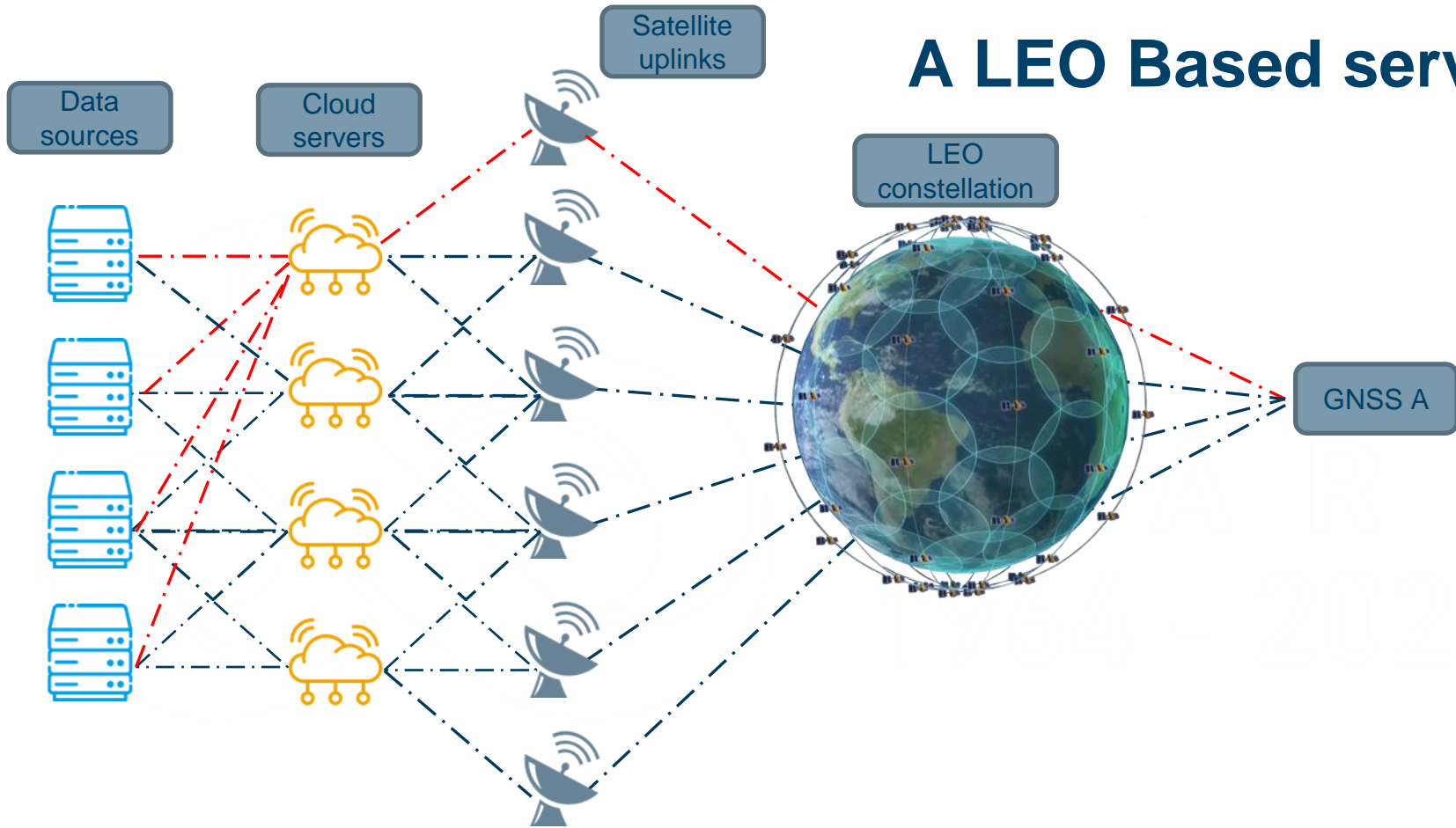


A LEO Based service

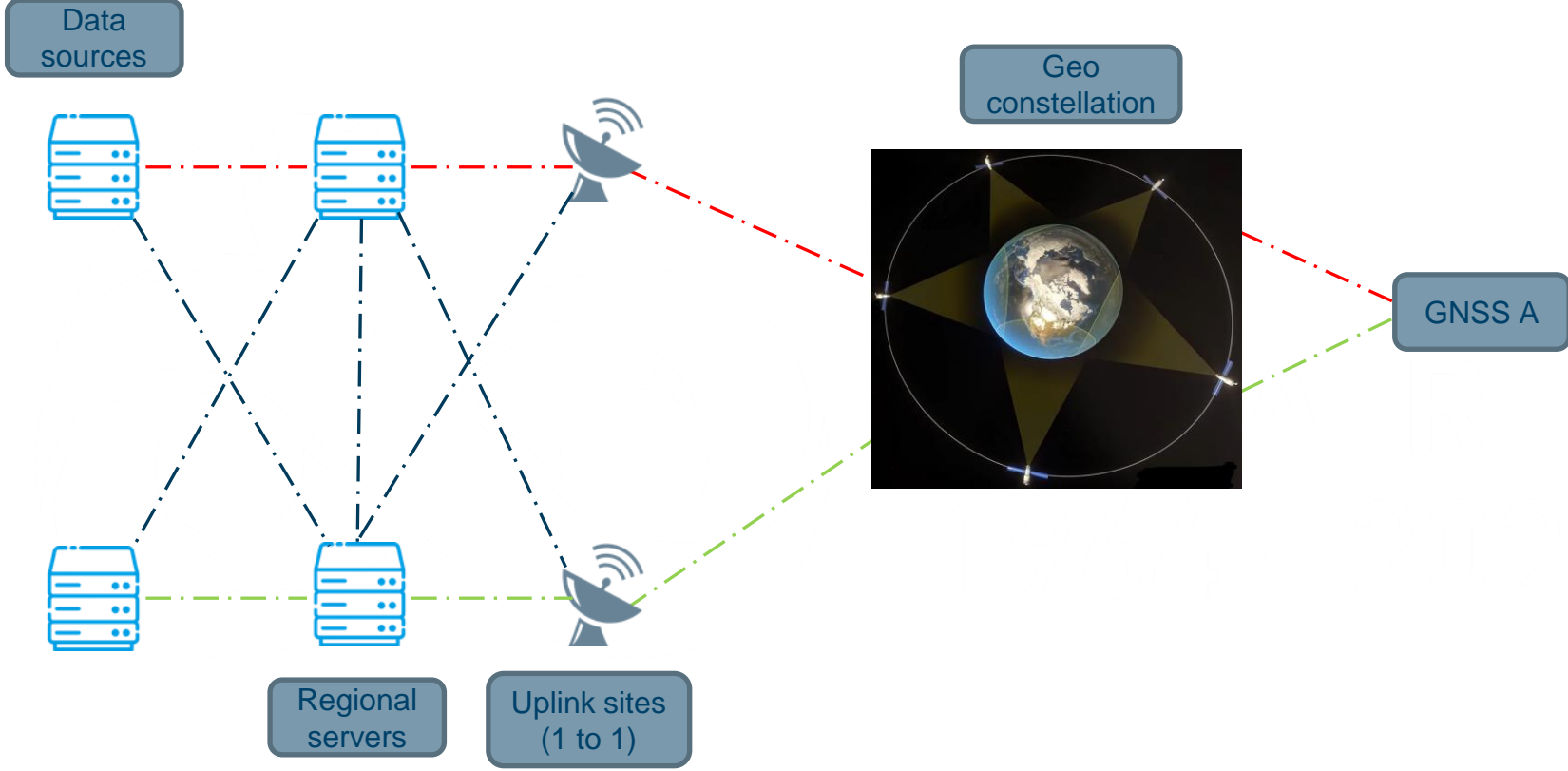
- **66 Active Satellites**
 - 6 orbital planes with 11 satellites each
 - Plus 14 in-orbit spares
- **Low-Earth Orbit (LEO) (780km)**
 - Enables reliable communications anywhere in the world
- **L-band System**
 - Allows for transmissions even in adverse weather conditions
- **Satellite Crosslinks**
 - Creates low-latency, resilient, high-quality connections
- **Signal Strength**
 - Signal strength is 10x of Geostationary satellites



A LEO Based service



Geo Based Services



Comparison Table of LEO vs Geo (L-Band)

Component	LEO Burst/SBD Service (GSBD)	Geo Point-to-Multipoint Service (PMP)
Number of satellites	66 Active + 14 in-orbit spares (80) Constellation completed 2017-2019. 2023 launched final 5 spare satellites bringing total number of in orbit spares to 14.	L-Band GEO constellation now 5-6 in number I3-F5 (54°W) Launch 1998 (25 years) I4-F1 (143.5°E) Launch 2005 I4-F3 (98°W) Launch 2008 I4-F4 (25°E) ESA Alphasat Launch 2013 I6-F1 (83.5°E) Launch 2021 (I4-F2 replacement (2023)) I6-F2 Launch 2023 (Unexpected anomaly) Redundant coverage in Americas relies on I3-F5
Distance to Earth Slant range – SV to EUE	760km 780km (90°) to 2,740km (5°)	35,786km 35,768km (90°) to 41,121km (5°)
Signal Strength	32.5 dBW EIRP fixed (10 x Power)	Variable. Broadcast power determined by provider
Coverage	Pole – Pole	75° – 78° (North / South)
Satellite Redundancy: Number of satellites seen by a user at anywhere in the world at any time	2-4 Max in view 5-6 in Northern latitudes	Max. 2 – Some regions have no redundant coverage
Masking: If I get masking, will it be permanent if I am stationary?	No	Yes
Military Spec.	Yes	No? PMP frame data is not encrypted. Payload data is scrambled with a 16-bit scrambling vector (v. weak)

Comparison Table of LEO vs Geo (L-Band)

Component	LEO Burst/SBD Service (GSBD)	Geo Point-to-Multipoint Service (PMP)
Does the signal become weaker and lower on the horizon the further from the equator I go?	No	Yes
Does the satellite system have 2-way communications	Yes	No
Outages in 2023	None	4
How many satellites is a single satellite are cross linked with	15	None

REDUNDANCY vs INDEPENDENCE

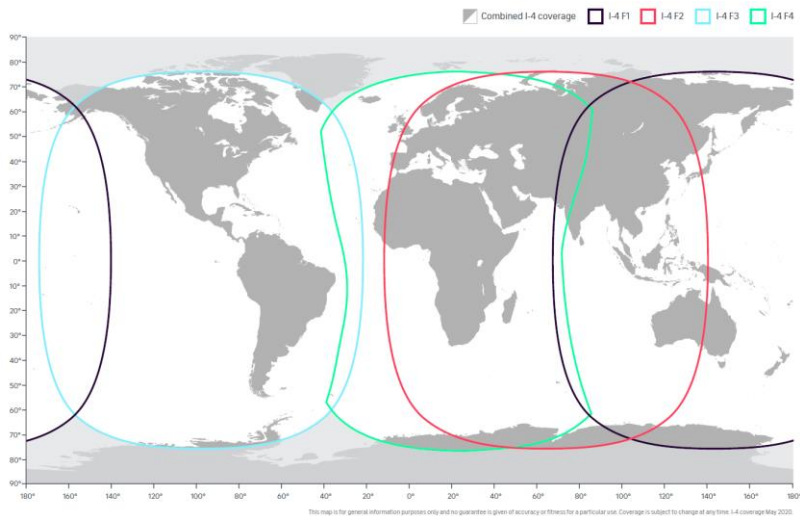
What do we mean by redundancy and independence?



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Why Now?



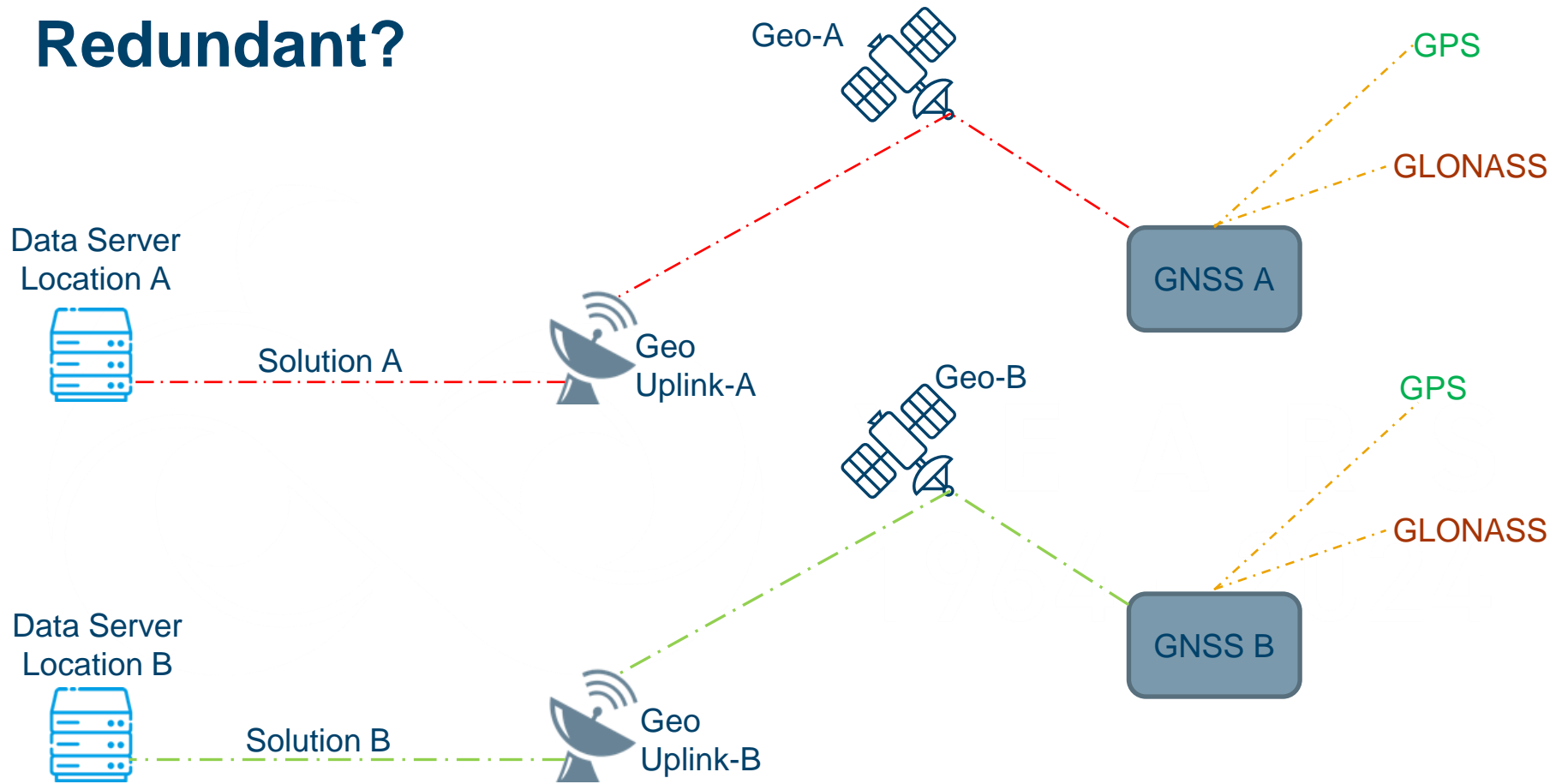
- Legacy Geostationary (Geo) delivered augmentation considered as a single point failure with high severity risk
- Consumer demand for enhanced performance and security
- Certain regions legacy Geo satellites do NOT provide a 'global' redundant service
- Aging assets (SV's are working beyond service life)
- Outages experienced (Australia affected for several days)
- Not pole – pole (75° - 78° North / South)
- Line of sight challenges in and around infrastructure
- Weaker L-Band signal (35,000km)
- Discontinuation of IALA

Why Now?

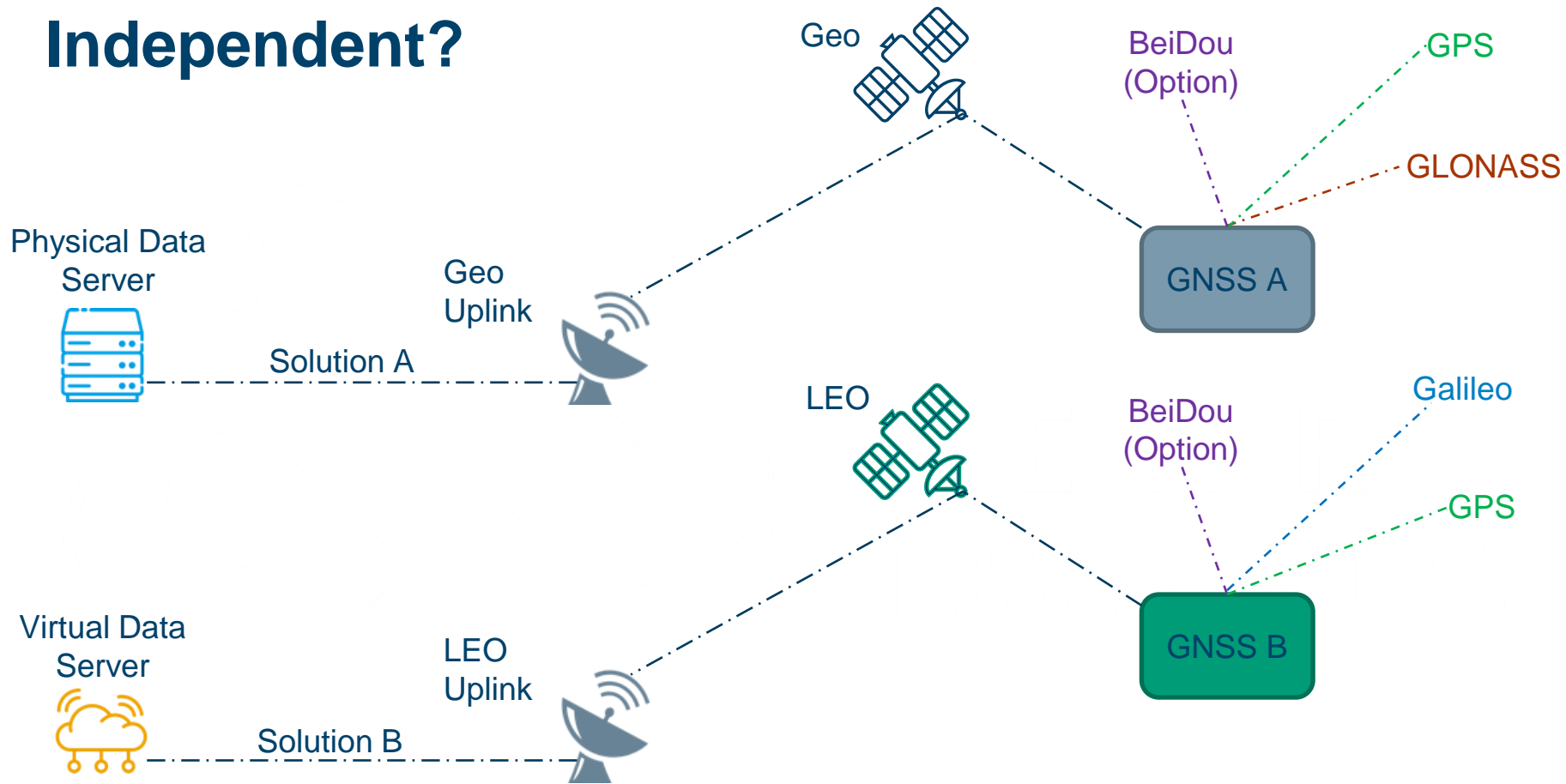
Date	Satellite	Outage Start	Outage Restored	Down time
10/04/2023	98°W	18:42:00	23:59:59	05:17:59
11/04/2023	98°W	00:00:00	07:54:00	07:54:00
16/04/2023	143.5°E	22:55:00	23:59:59	01:04:59
17/04/2023	143.5°E	00:00:00	23:59:59	23:59:59
18/04/2023	143.5°E	00:00:00	20:30:00	20:30:00
19/04/2023	54°W	07:44:00	12:25:00	04:41:00
30/04/2024	54°W	14:09:00	14:15:00	00:06:00
07/05/2023	54°W	13:20:00	20:22:00	07:02:00
11/07/2023	64°E	05:02:00	07:37:00	02:35:00
23/07/2023	143.5°E	18:00:00	20:24:00	02:24:00
17/08/2023	54°W	10:24:00	23:59:59	13:35:59
18/08/2023	54°W	00:00:00	22:20:00	22:20:00
17/09/2023	143.5°E	21:45:00	23:59:59	02:14:59
18/09/2023	143.5°E	00:00:00	02:38:00	02:38:00
06/01/2024	143.5°E	16:29:00	17:37:00	01:08:00
14/01/2024	83.5°E	08:00:00	11:21:00	03:21:00
24/01/2024	83.5°E	06:50:00	08:40:00	01:50:00
11/02/2024	83.5°E	17:30:00	21:50:00	04:20:00
14/02/2024	143.5°E	14:29:00	15:13:00	00:44:00

> 7 days

Redundant?



Independent?



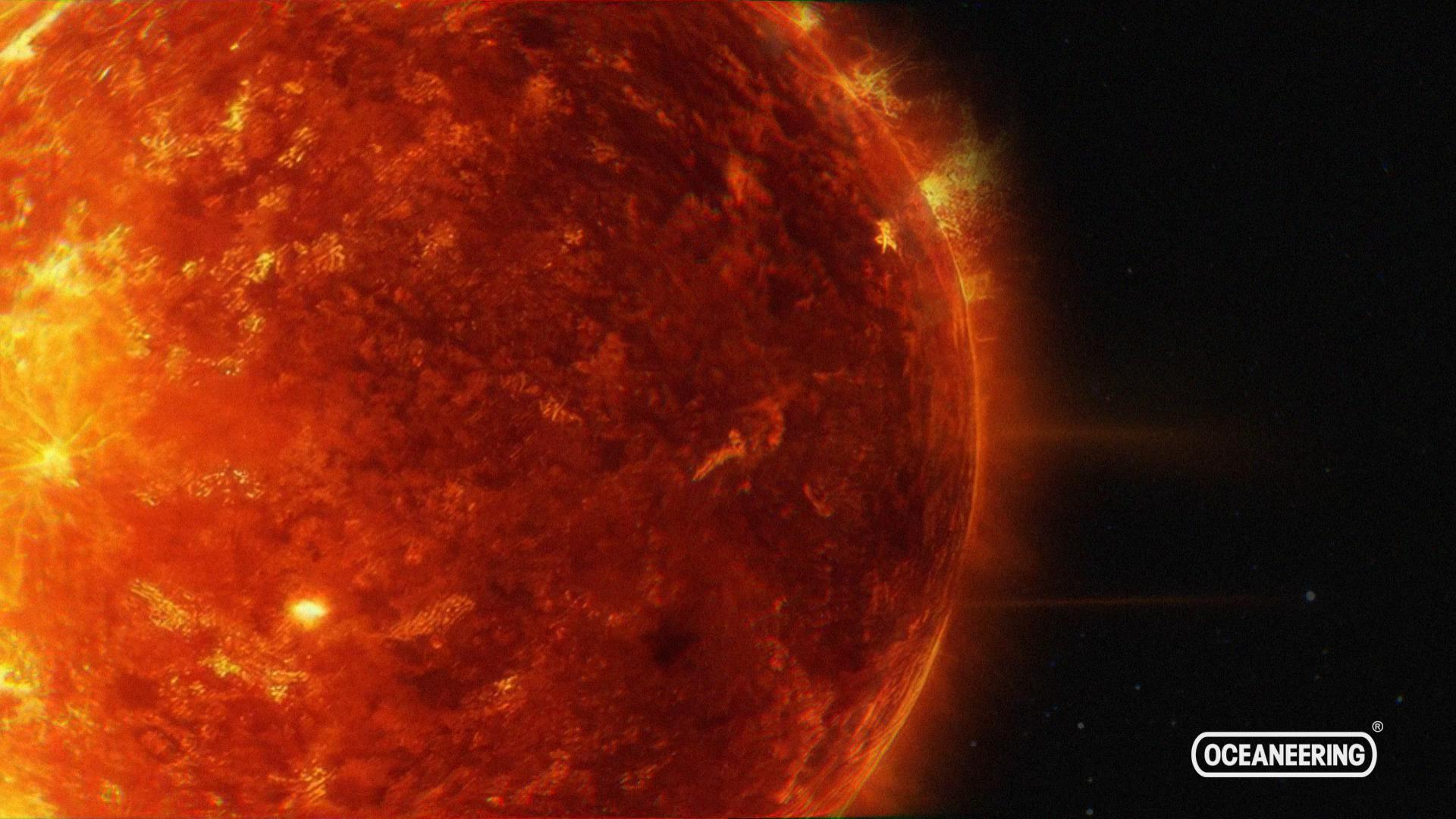
SOLAR CYCLE 25

How can we protect ourselves from Solar Cycle 25?



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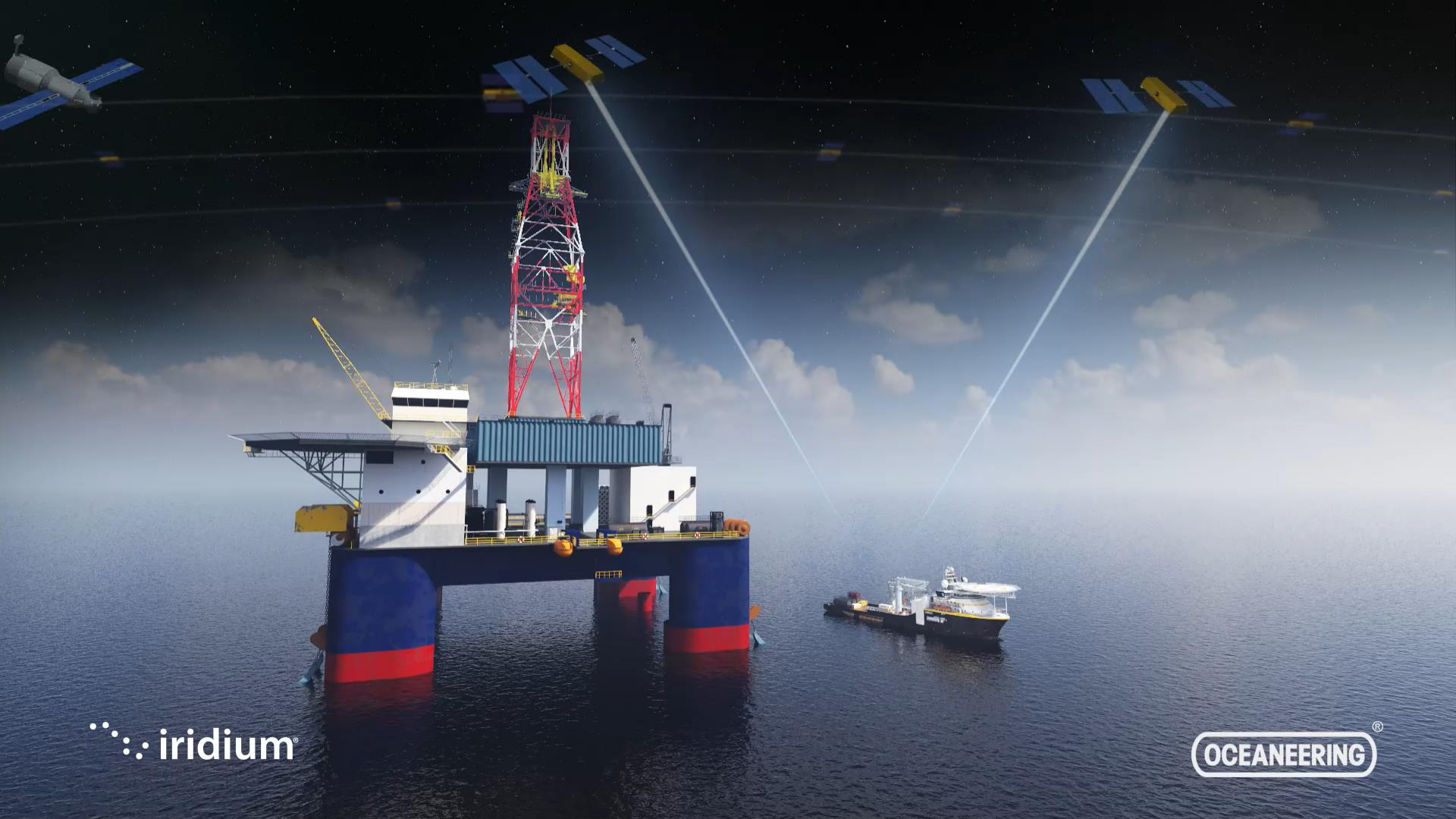
USER EXAMPLES

Use cases of a LEO delivered GNSS Augmentation service



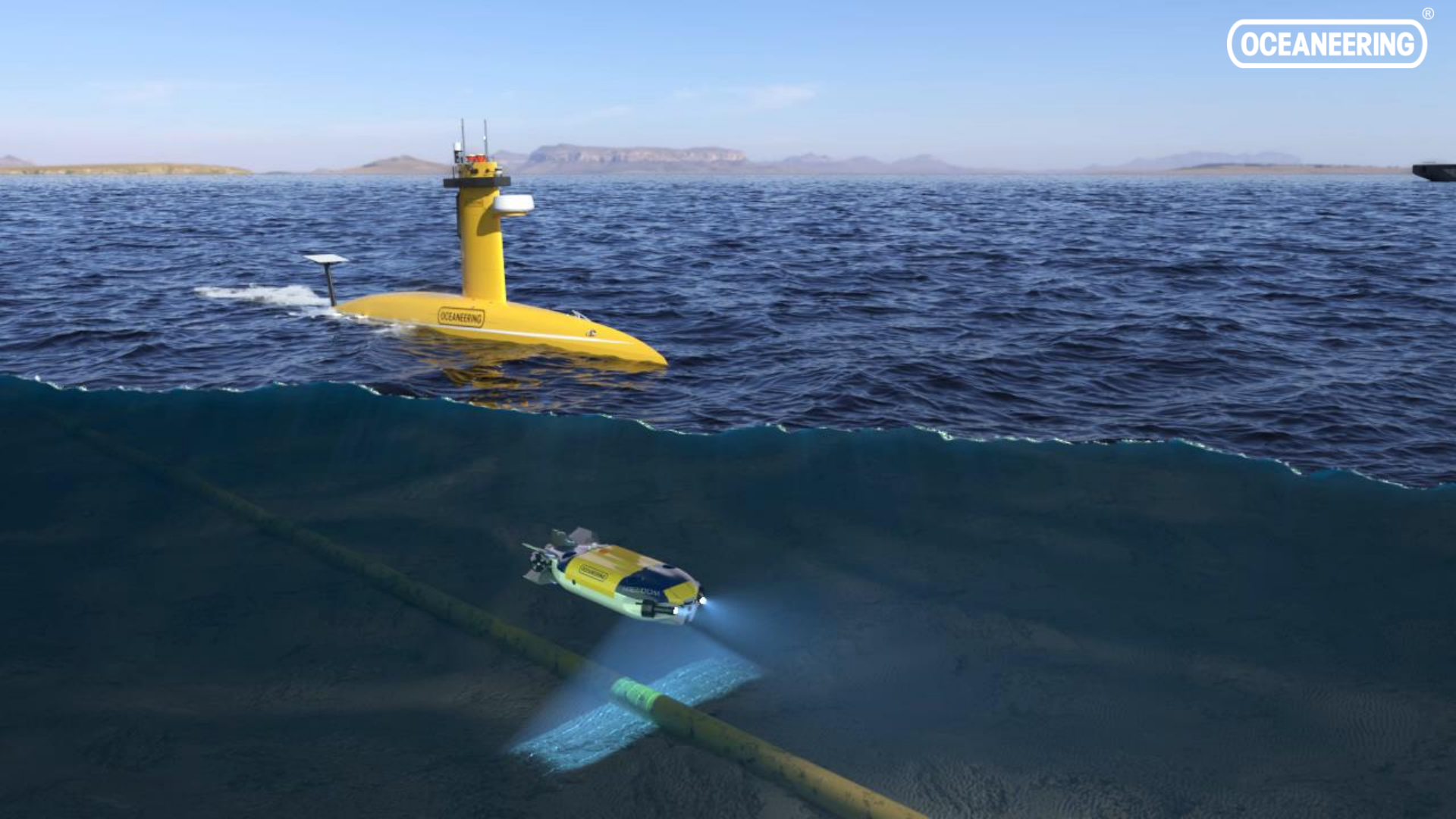
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iridium

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DriX at a Glance



Dimensions

- 7.71m | 0.82m | 2m (Length | Breadth | Draft)
- Weight ~1.4Te

Characteristics

Speed: Up to 13 kts

Endurance: 10 days

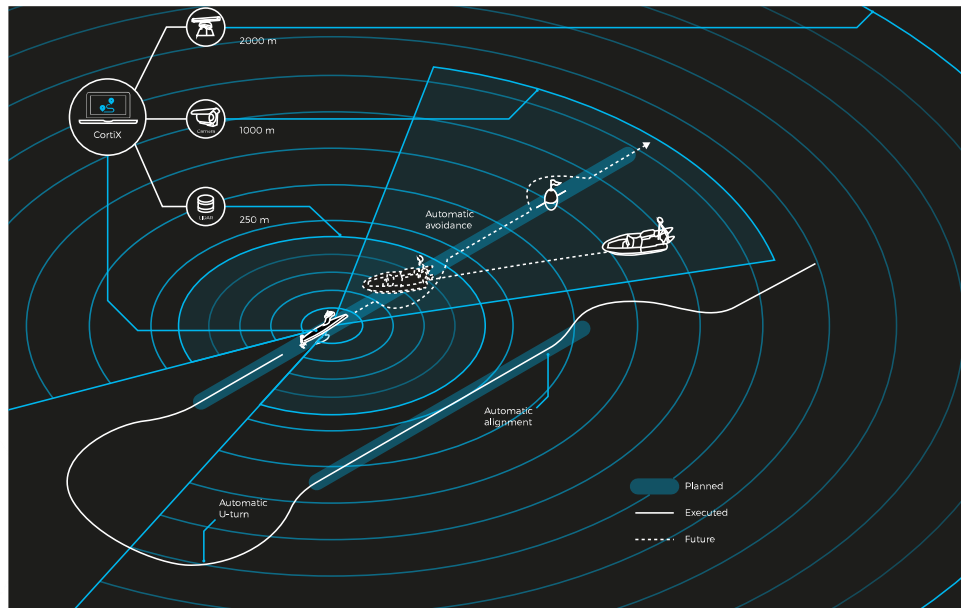
Fuel Capacity: 250L /Average consumption 2L/Hr

Retractable keel for stability and optimised sensor mounting.

True Redundant GNSS

LEO delivered GNSS augmentation

Geo delivered GNSS augmentation



The DriX is equipped with multiple **perception sensors** used by the Obstacle Avoidance System:

The DriX is interfaced with different **communication** means to cover SimOps with a mother vessel and over the horizon operations.

The DriX is also outfitted with various **safety equipment** to ensure its compliant with ColRegs and safe maritime operations.

Summary

To meet ‘full’ independence and redundancy, the following should be considered:

- Satellite Communications Links
- Constellations (GPS / GLONASS / Galileo / BeiDou)
- Data algorithms (augmentation)
- Coverage
- Masking/Blockages
- Scintillation/Spoofing/Jamming
- Risk

Other Considerations

- Free-to-Air Satellite Based Augmentation Systems (SBAS)
- Free-to-Air Precise Point Positioning (Galileo HAS)
- Internet based delivery (backup)
- Jamming / Spoofing
- Alternative PNT (Satellites)
- Xona Space Systems (LEO delivered PNT)
- Internet from the sky



Connecting What's Needed with What's Next™