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Q1:

Ans: Field robotics in its own rite faces numerous difficulties and challenges, but underwater robotics have its own myriad of unique challenges making it extra difficult. Four such unique challenges include:

1. The deeper an underwater robot operates, the higher the water pressure it must withstand, which can cause mechanical, structural, and sensor failures if not designed with robust and pressure-resistant design and materials.
2. Unlike ground or aerial environments, radio wavers are ieffective underwater, making communication with underwater robots a challenge, thus requiring alternative methods like acoustic communication having high latency and limited bandwidth posing significant constraints for data transmission.
3. In featureless environments, such as open water or barren seabeds, traditional visual cues used for navigation and localization fail. In addition to that, due to underwater being a GPS-denied environment, robots face significant challenges in navigation and localization.These two reasons makes it challenging for underwater robots to orient themselves to accurately map their surrounding or maintain a stable course.
4. To compensate for lack of visual features, underwater robots need to rely of non-visual sensors like sonar, inertial measurement units, or magnetic compasses, thus limiting the degree of autonomous exploration that can take place.

Q2:

Ans: The gravitational field around an ellipsoid approximating Earth's shape varies due to the uneven distribution of mass within the Earth and the ellipsoid's varying distance from the Earth's center of mass. This variability in gravity affects marine navigation by introducing errors in gyroscopic and accelerometric instruments used for dead reckoning, necessitating advanced correction algorithms and geophysical models to maintain navigational accuracy.

Q3:

Ans: The issue of drifting being observed is because the submarine's buoyancy is not properly balanced and vertically aligned with the center of gravity causing it to pitch or roll instead of maintaining a level orientation. To fix this, we would need to adjust the distribution of weight and buoyancy within the vehicle to ensure it is evenly balanced around its center of gravity and is vertically aligned.

Q4:

Ans: For the provided task of collecting volcanic debris from the seafloor, a Remotely Operated Vehicle (ROV) would be suitable due to its expanded capability to maneuver in complex terrain and its capacity to be equipped with manipulator arms for picking up objects.

The ROV Medea would be an excellect existing solution of choice given its robust design and previously being used for seafloor operations including sample collection of rocks and sediments which aligns with the requirements of collecting volcanic debris, in addition to have advanced capabilities of precise maneuvering, operating for extended durations, and using manipulators arms.

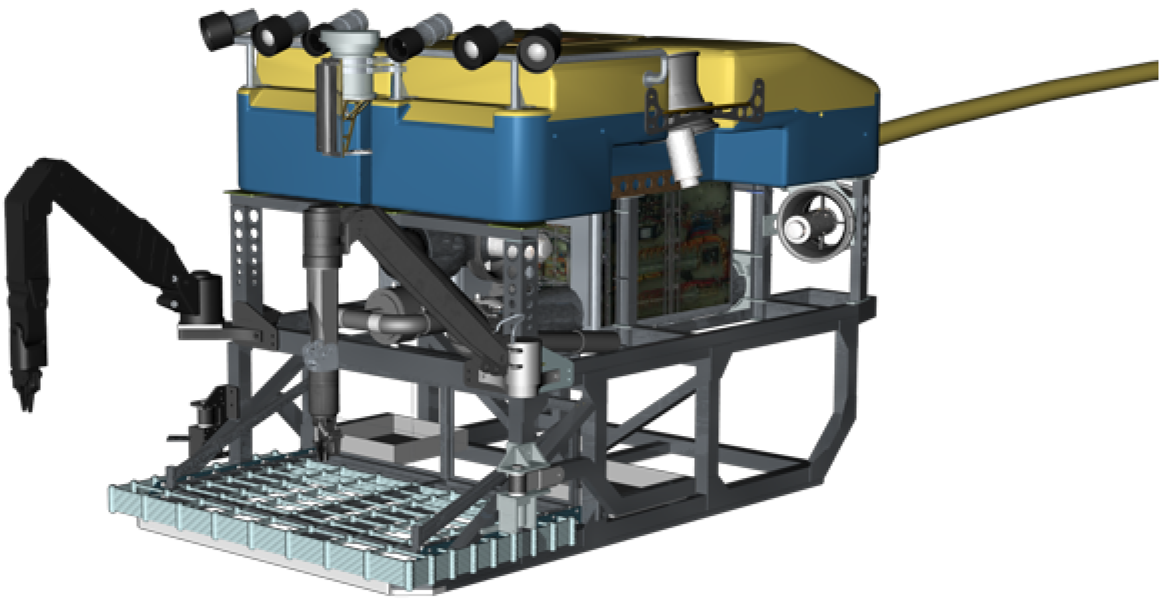

Figure: ROV Medea with robotic manipulator arm for sample collection

Q5:

Ans: At a depth of 5000 meters, an underwater robot could utilize any baseline acoustic positioning for localization, for the sake of this we can use ultra-short baseline (USBL) acoustic positioning, which involves sending acoustic pings from a transceiver on the robot to transponders on the seafloor or surface level vessel, and then calculating position from the return signal.

A positive attribute of USBL is that it can provide accurate positional information in deep-water (which is a GPS-denied envirobment).

On the flip side, a negative attribute is that its accuracy can be affected by variations in water properties such as temperature, salinity, and pressure, which can alter the speed of sound and thus the signal transmission.