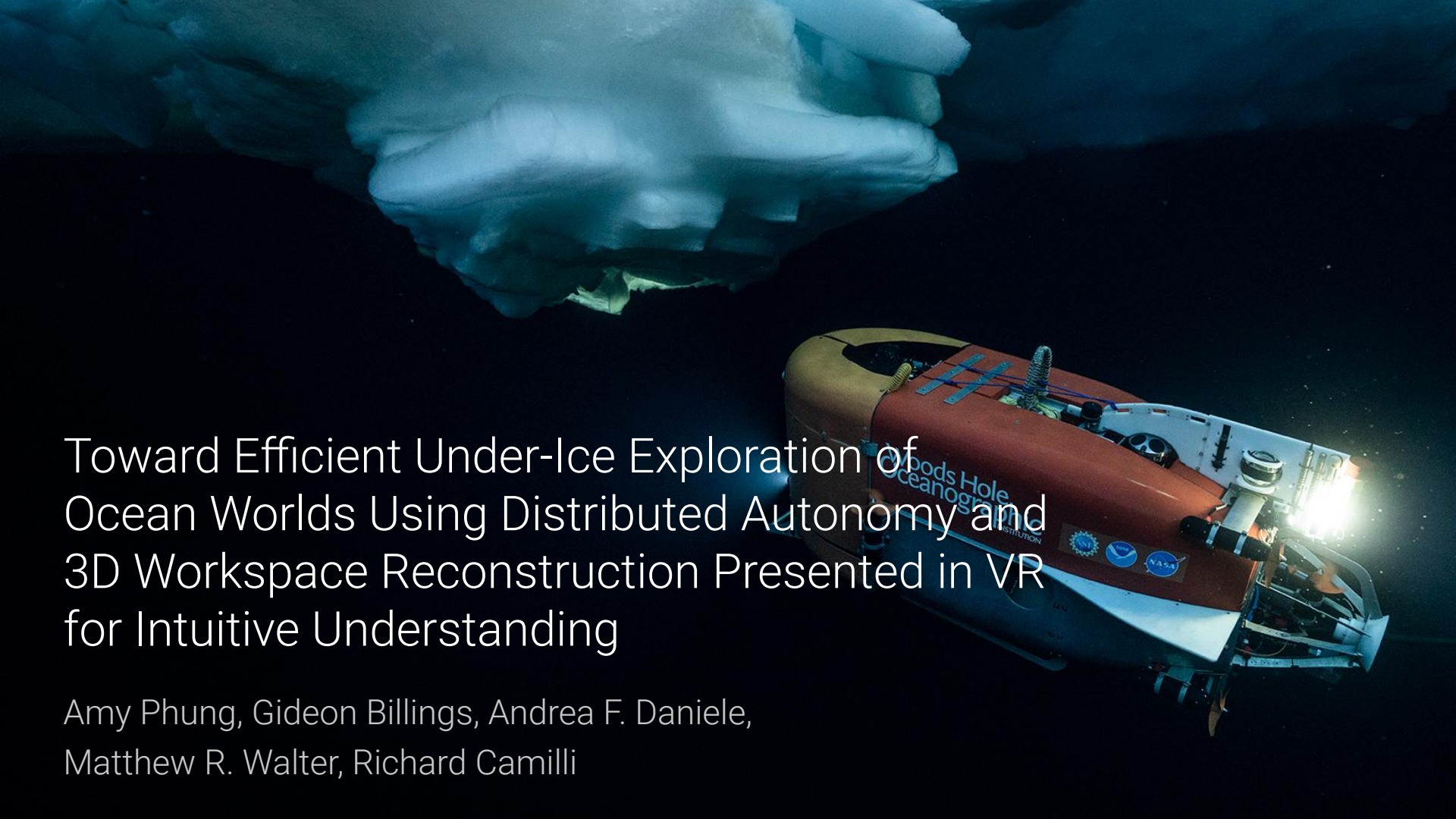
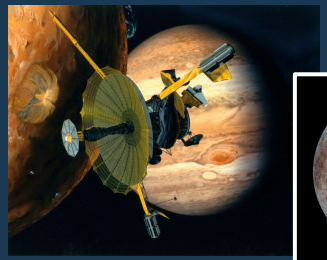


Toward Efficient Under-Ice Exploration of Ocean Worlds Using Distributed Autonomy and 3D Workspace Reconstruction Presented in VR for Intuitive Understanding

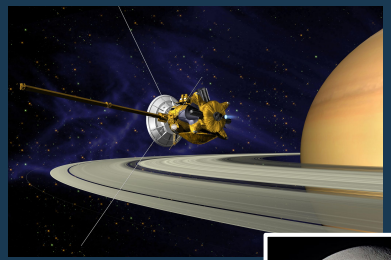
Amy Phung, Gideon Billings, Andrea F. Daniele,
Matthew R. Walter, Richard Camilli

Ocean Worlds Exploration

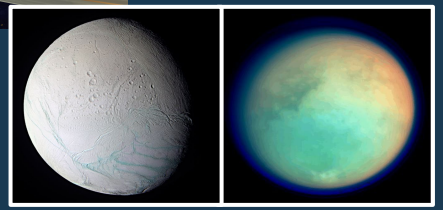


Galileo probe

Europa



Cassini probe

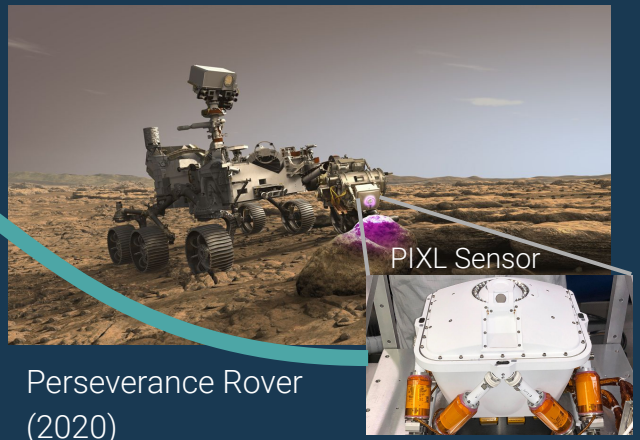


Enceladus

Titan

Mars Exploration

Viking Lander (1976)

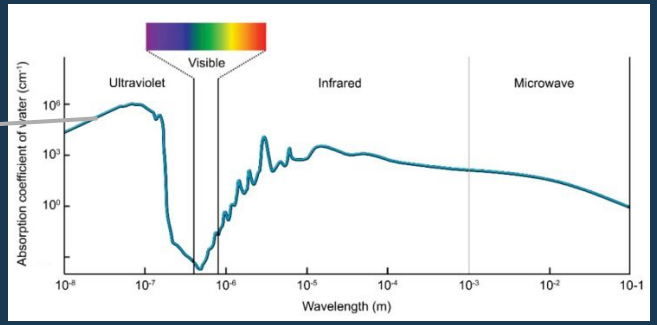


Perseverance Rover (2020)

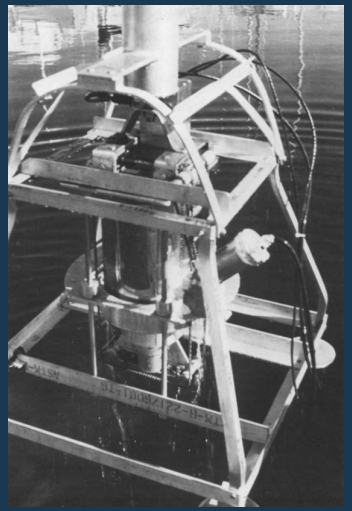
Images courtesy of NASA

Underwater XRF

Rapid X-ray attenuation underwater

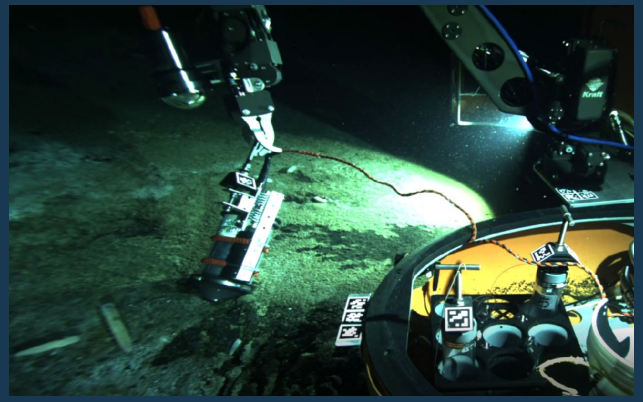


Spagnolo et al. (2020)



Wogman and Nielson (1976)

J. Breen et al. (2012)



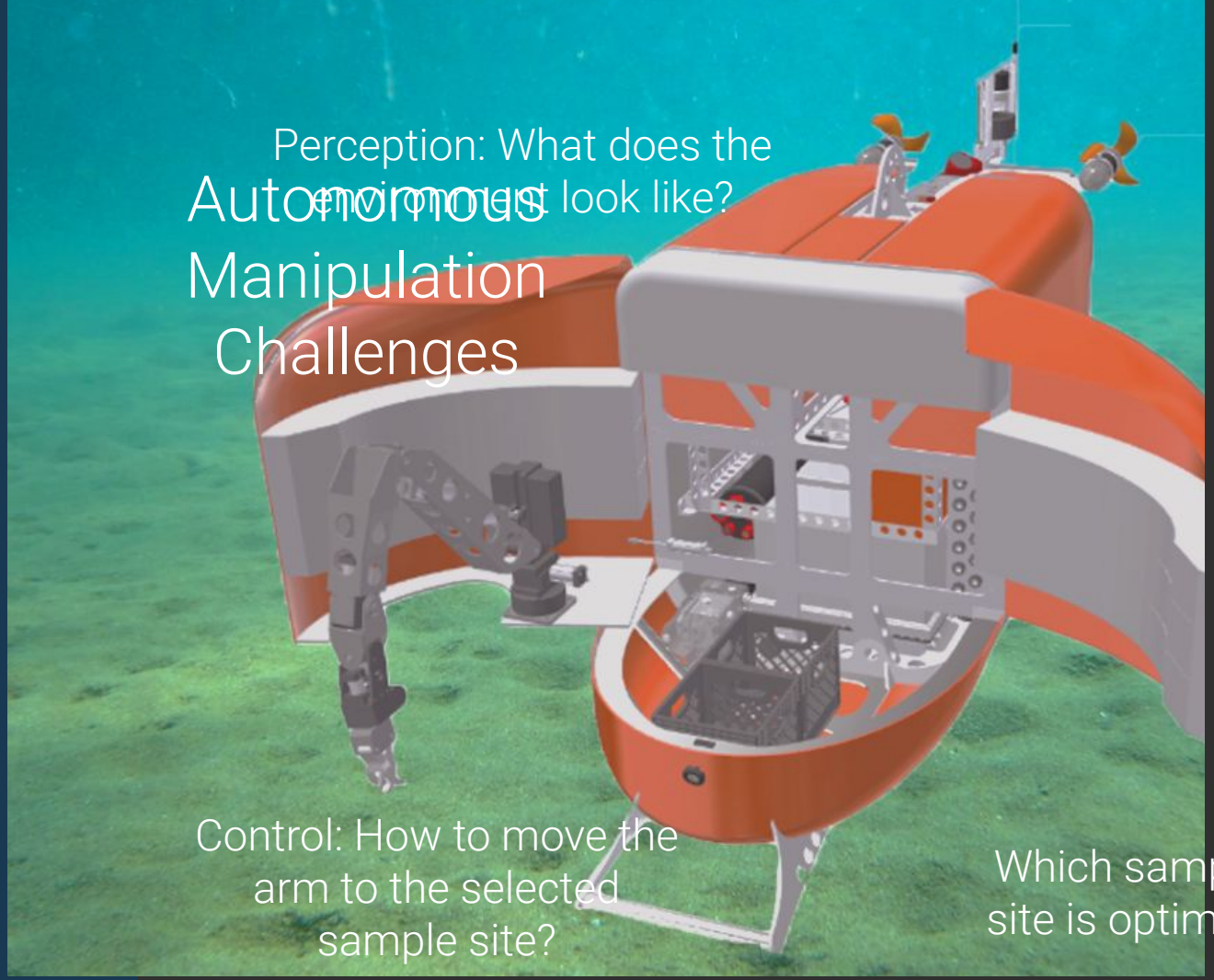
Our Team (unpublished - 2021)

~1000m^2 resolution
Hours per sample

~10m^2 resolution
Tens of minutes per sample

~0.0001m^2 resolution
Minutes per sample

Autonomous Manipulation Challenges



Perception: What does the environment look like?

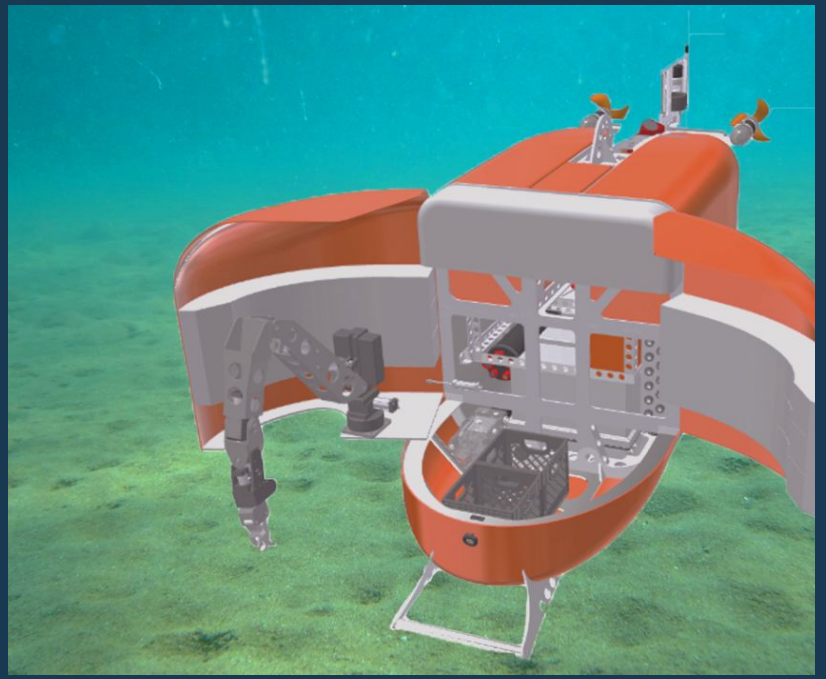
Control: How to move the arm to the selected sample site?

Which sample site is optimal?

Robotic Manipulation

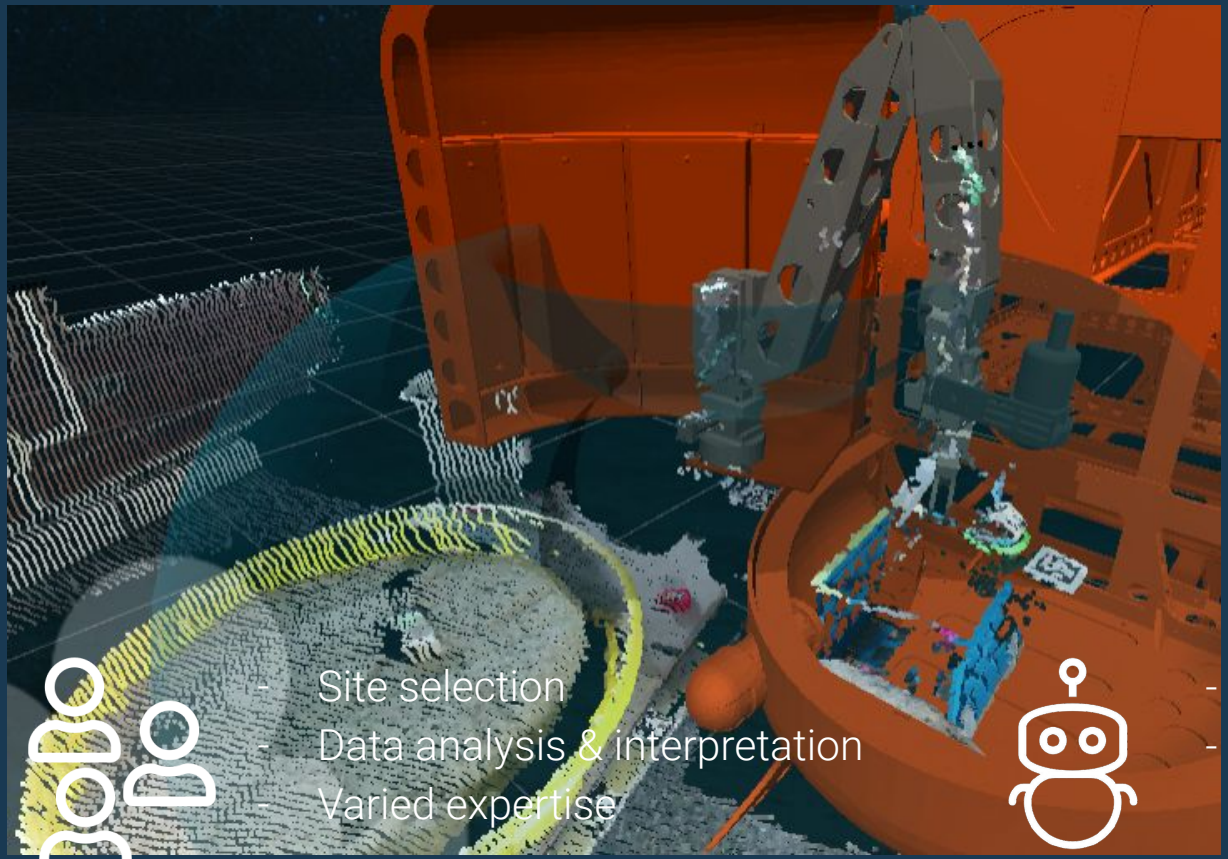
Teleoperation via Joystick

- Most commonly used
- Requires high-bandwidth, low-latency connection



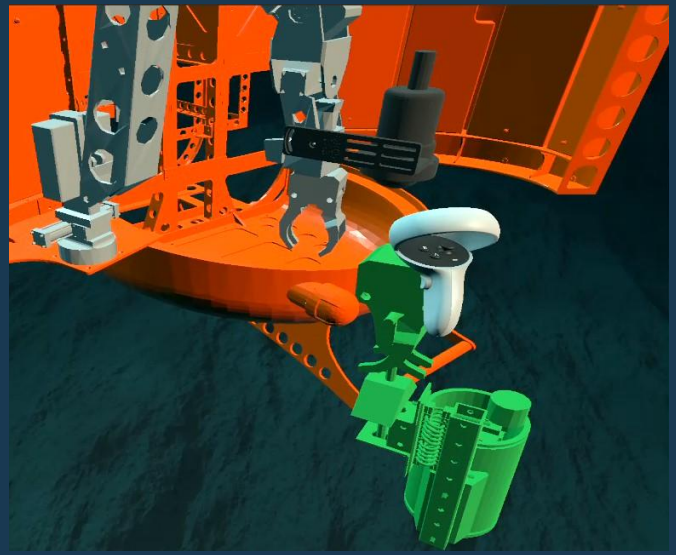
Autonomous Manipulation

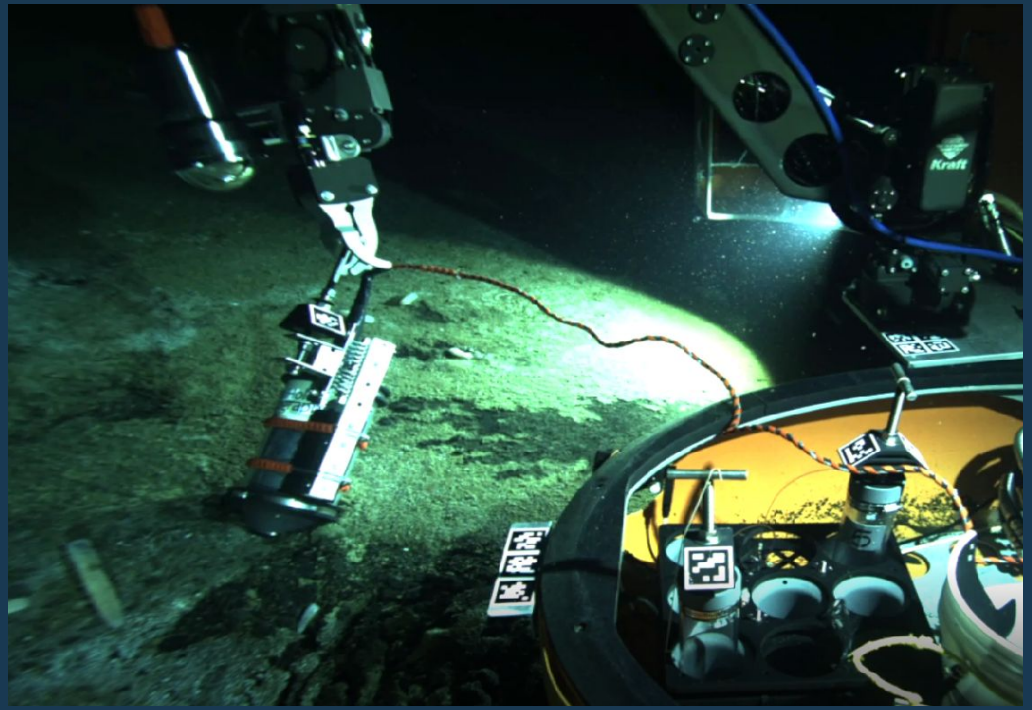
- Active area of research
- Full autonomy too risky



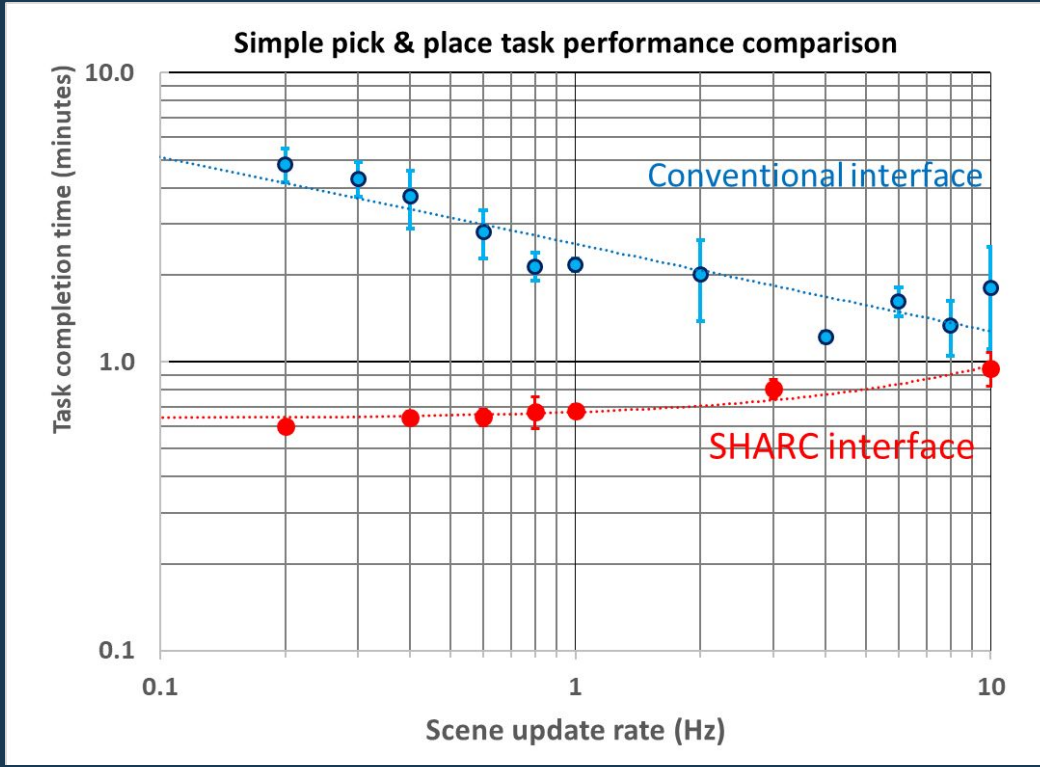
SHARC: SHared Autonomy for Remote Collaboration

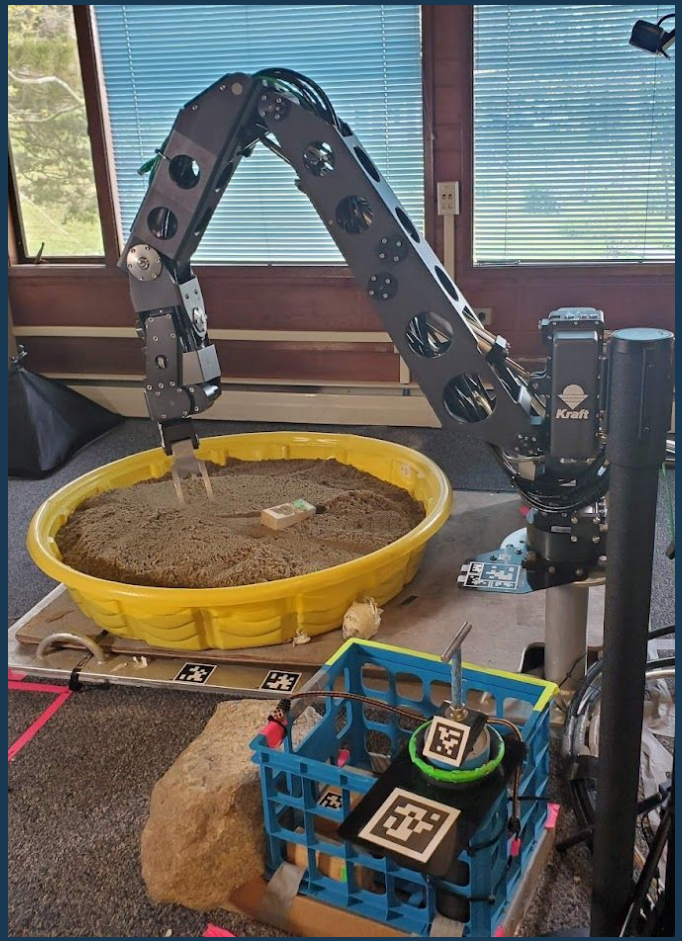
AbSciCon 2022



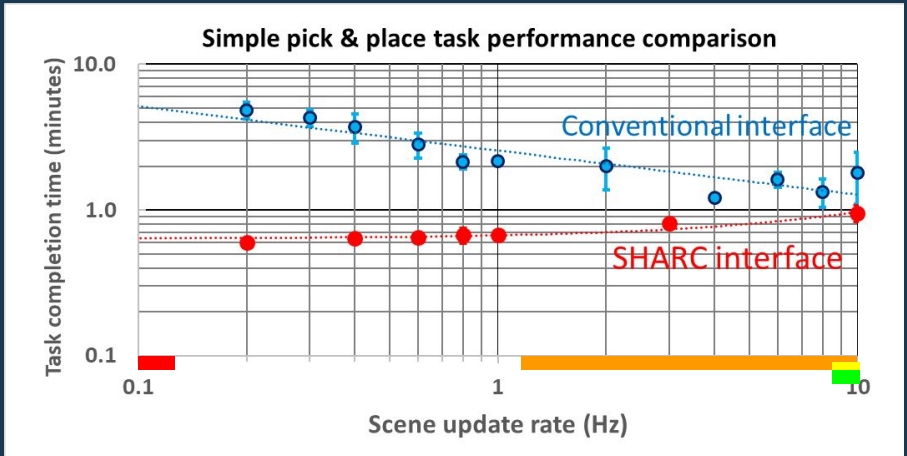


SHARC Field Demonstration





AbSciCon 2022

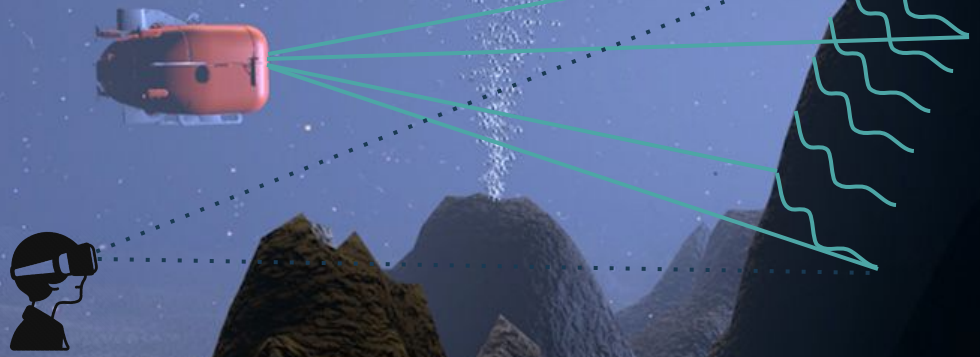


	Acoustic 🔴	Optical 🟠	Light Fiber 🟡	Conventional tether 🟢
Bandwidth	30-100 kbit/s	1-10 Mbit/s	Multiple Gbit/s	Multiple Gbit/s
FPS*	0.03-0.125	1.25-12.5 FPS	**	**
Est. Task Completion Time (Joystick)	5:00	1:18-2:30	1:18	1:18
Est. Task Completion Time (SHARC)	0:40	0:42-1:00	1:00	1:00

*FPS Estimate assume SD resolution (640 × 480px) from 2 camera feeds
**Hardware limited

Immediate Next Steps:

- Quantify effects of latency
- Improve perception system



Looking Forward…

Thanks For Listening!

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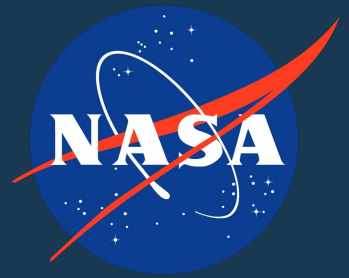
Website: amyphung.github.io

Supported by:



NASA PSTAR # NNX16AL08G, NSF #IIS-1830660 and IIS-1830500