TOWARDS ICY WORLD EXPLORATION WITH AUTONOMOUS VEHICLES: DESIGN OF AN AUTOMATIC DOCKING AND EGRESS SYSTEM FOR LONG RANGE UNDER-ICE AUVs. E. B. Clark[1], W. C. Stone[1], K. Richmond[1], C. Flesher[1], P. Kimball[1], M. Scully[1], L. Lindzey[1], S. Lelievre[1], B. P.Hogan[1], V. L. Siegel[1], D. Rickel[1], K. Huffstutler[1]. [1]Stone Aerospace – 3511 Caldwell Lane, Del Valle, TX 78617. Primary author email: evan.bock.clark@stoneaerospace.com

Why This is Important to Astrobiology: The most promising locations in our solar system to search for extant extraterrestrial life are sub-ice oceans such as those on Europa and Enceladus, but many challenges remain before such missions are technically feasible. Here, we describe a sub-ice autonomous vehicle docking system designed for studies of icy moon environments and their terrestrial analogs. We expect the development of a robust autonomous egress and data retrieval methodology to become a key technological advance towards planetary-scale robotic under-ice exploration and the ability to search for life beneath the outer planet icy moons.

No Data Link, No Mission Success: The key to a successful autonomous sub-ice science mission (on Earth or elsewhere) is assured return, rendezvous, and capture of the mobile portion of the mission and the transfer of its data payload to an uplink station. On Europa, this would be the lander system, which would then uplink to an orbiter and then to the DSN.

Underwater exploration is notoriously difficult because electromagnetic attenuation prevents high-bandwidth radio and optical communication with the external world. The difficulty is exacerbated beneath an ice ceiling, where vehicles are forced to return to a precise location for data uplink and recovery instead of surfacing anywhere. To date, this has severely limited exploration range under ice and every long-range AUV mission on Earth has returned to open water for recovery.

ARTEMIS/SIMPLE Analog Mission: A reliable autonomous localization and docking system will greatly increase mission return by allowing vehicles to range farther afield and pursue more scientifically valuable missions. The ARTEMIS vehicle (part of the NASA SIMPLE ASTEP project) will attempt the first-ever long-range scientific exploration under the McMurdo Ice Shelf during the 2015/16 Antarctic field season as a terrestrial analog for a Europa ocean mission. ARTEMIS will utilize a combination of inertial and Doppler acoustic dead-reckoned navigation, followed by an advanced autonomous three-stage rendezvous and docking system to perform 20 km round-trip missions with deployment and recovery though a single access hole drilled through sea ice at the shelf edge.

Navigation. We describe the performance of the vehicle's dead-reckoning navigation system, which determines (probabilistically) how closely it can be expected to return to the vicinity of the access hole. That performance dictates the range over which the multi-stage docking system must function.

Docking system design. We describe the mechanical, sensor, and software design of a fully autonomous docking system. The system includes an ultra-short baseline (USBL) medium-range acoustic homing system, visual recognition of an illuminated target, and vision-based final approach to within the docking adapter's 5 cm capture radius.

Preliminary test results. We present preliminary test results of the docking system both from test tank experiments and from under-ice field trials of the docking system in Lake Superior, Michigan in April 2015.

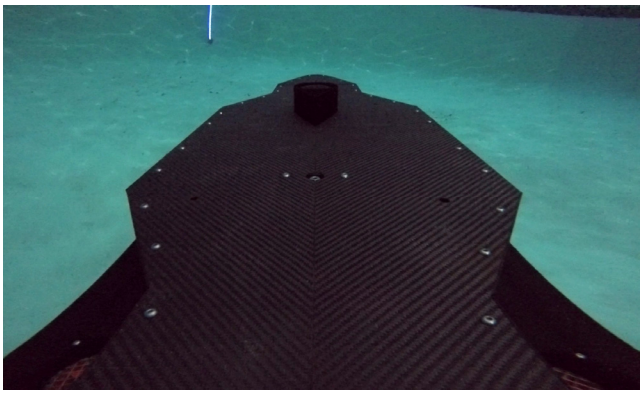

Figure 1: External view of robot approaching illuminated docking target.

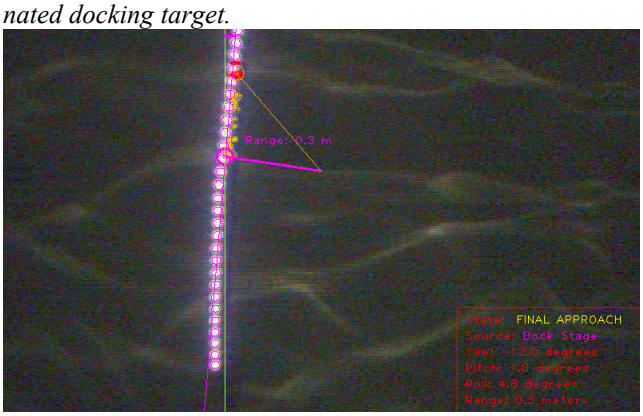

Figure 2: Robot's-eye view of docking target just before docking, with computer vision annotations overlaid.