PRACTICAL SOLUTIONS

High-Speed Handlebars

How more-intuitive controls can improve safety and maneuverability at ever-increasing boat speeds and slamming loads.

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Those who work on high-speed boats know that there is a world of difference between traveling with someone who believes he's the best boat driver in the world and with someone who actually is.

Skilled operators cause less impact exposure, fewer accidents, and ejections as well as less damage to hulls and drivetrains. Investigation of high-speed boat-accident reports reveals that pilot error is the No. 1 cause of accidents.

During the last three decades, high-speed boats built for professional use have been designed and powered for higher and higher speeds, often in excess of 50 knots. This evolution is a testament to advances in hull design and in propulsion refinement; however, the demands on operator skills grow exponentially with speed. As boats travel faster, required pilot response times contract while risks of impact-induced injuries, pilot errors, and ejections increase. In spite of those practical realities, onboard operator interfaces have remained largely unchanged from the standard steering wheel and throttle-lever controls created decades ago for 20-knot boats.

Ullman Dynamics has worked for decades to optimize these conventional helm stations for high-speed operations (see "Designing Consoles for Speed," *Professional BoatBuilder* No. 141), but the more we looked at the standard control systems, the speed of modern boats, and the capacities of

Above—*A prototype of a steering bar for twin Volvo Penta D4s running through waterjets. Throttle controls are synchronized and the buckets separately controlled through the twist grips. This system is intended as an improvement over conventional wheel and throttle-lever helm stations, and offers the prospect of better boat control and driver stability, particularly on high-speed powerboats.*

the human body and mind, the more we saw a need for a fundamental change. In 1998 we launched a project to develop a safer, more intuitive, and more efficient steering and control system.

Preliminary Research

The development of a new system was based on the following facts and assumptions:

- Safety can be enhanced if response times can be reduced.
- Both hands and both feet are needed to fully control and protect the human body exposed to whole-body impact.
- A balanced spine and a symmetrical body posture are safer than asymmetrical and nonbalanced postures.
- A boat operator needs input from hands and feet, arms and legs to get adequate tactile information and feel the hull's movements, in all dimensions.
- Slamming forces on the operator's body should not interfere with his control of direction and speed.
- To reduce physical fatigue and extend endurance, the least-possible static muscular load should be required to operate the boat.
- Optimal tactile and visual feedback enhances maneuvering precision.
- Response times can be reduced and precision can be enhanced if speed and steering are controlled simultaneously, while maintaining postural control, even under exposure to impacts.

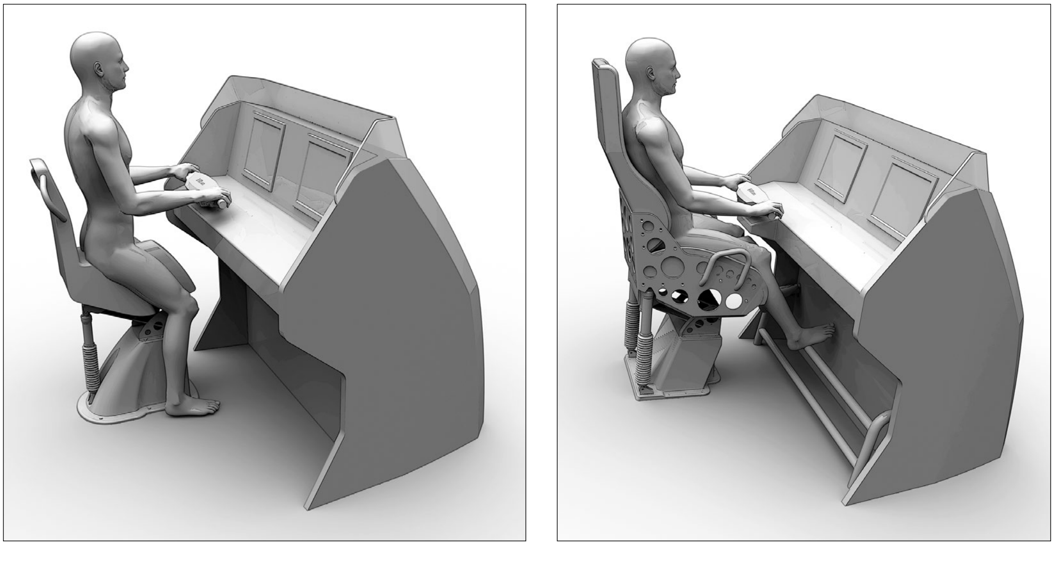
We started by studying control systems associated with other challenging tasks that include significant motion exposure, short response times, risk of injury, and need for postural control. For instance, it was apparent that no motorcycles have successfully been operated with steering wheels and throttle levers, or foot-controlled accelerators for that matter. Instead, handlebars with twist throttle controls are the norm.

Continued scientific analysis of the dynamics of steering, shifting, and throttle controls on high-speed boats yielded practical considerations—mainly neurophysiological and perceptual—to be factored into the new design.

Intuitive operator interfaces can enhance situational awareness. When operating high-speed boats in challenging conditions, different parts of the brain handle different parts of the operation. Training and experience lead to greater skill, as the central nervous system gradually moves the basic control and handling of the boat from conscious decisions in the brain cortex to reflex actions in the brainstem. That frees the operator's perceptual, analytical, and intellectual capacity for conscious selection and processing of mission-critical information coming in through eyes and ears. The speed with which control actions transition from conscious action to reflexes is greater when the action is intuitive. Similarly, the shorter the time from the command given until the actuation perceived, the faster the new reflex paths will develop.

In addition to intuitive actions, **multi-modal feedback** allows for improved operator performance. Helmsmen who can both see *and* feel what they are doing and what they have just done, benefit from their brains receiving more information from multiple senses to be correlated and applied to throttle control and steering. For example, if the angular position of the steering bar always correlates to a specific rudder angle, you will always know what that angle is by feeling and looking at the helm and remembering how it should feel when applied at speed. When copilots can see the actual rudder angle by observing the angle of the steering bar, it is a safety bonus, as they will know what is coming.

To maximize intuitive interfaces, the design should exploit advantages of **fine-motor control**. Because the part of the brain that controls the hand is much larger than the part that controls the arm, greater precision is possible when twisting a twist grip than when pushing a lever back and forth. Similarly, the angle of the wrist is more sensitive and changes more than the angles in the shoulder and elbow. In practical terms, the brain has better control of how much the hand is twisted than of how far the hand is pushed or the arm extended. Another benefit is that the twist handle control is not affected by the pushing or pulling motions of bracing actions.



*The handlebar-equipped helm station fitted with a straddle seat **(far left)** or a helm chair **(left)** should optimize the pilot's balanced and secure posture, and maximize tactile and visual feedback for precise maneuvering.*

Left—*An early prototype model for a single waterjet employed push-pull cables for throttle control. They were not durable enough to last in the marine environment.* ***Right***—*The author at the helm of a 7.5m (24.6') test RIB used for developing and refining the system with hydraulic steering and electronic throttle control of a single 250-hp (187-kW) outboard.*

With these design limitations and priorities in mind, we set out to define what we believed were attainable improvements that would enhance the safety of high-speed boat operations. We were looking for **shorter response times** for operators, who need all the seconds they can get to respond to external stimuli and perform maneuvers at speed. **Greater precision** in the controls would allow for better selection of the optimal track in high seas to reduce slamming, as well as safer approaches, holding relative position, and maneuvering in boarding operations and entering stern-ramp retrievals. **Simultaneous control** of steering and throttling (and of buckets on waterjets) would shorten response times, and facilitate precise tactical maneuvering. Also, **full control** of steering and thrust should be achievable even when all limbs are bracing and supporting the body during dynamic vertical and horizontal accelerations. **More tactile input** is possible with optimal (wide) spacing between hands and feet, which should be in contact with structures fixed to the boat, not moving relative to it. This tactile input gives the trained operator's "reflex ride-control system" a constant flow of information about the boat's motions and orientation that will be processed unconsciously by reflex.

Prototype Development

Building a steering bar system to control drivetrains on boats presented significant challenges. For instance, hydraulic helm pumps normally rotate through nearly 1,000° from lock to lock; a steering bar should have only one-tenth of that. Integrating throttle, shift, and trim commands into the steering bar presented further challenges. To make them function was one thing; to engineer them to endure the harsh maritime conditions sandwiched between burly operators and powerful drivetrains was quite another.

The earliest versions of the system were built for single drivetrains. The first was for a 250-hp (187-kW) outboard, the second for single waterjet, and the third for an inboard/outboard. All required hydraulics to handle the steering forces. (Initially, the single waterjets were steered just by push cables, but this proved insufficient for advanced maneuvering.)

In addition to the change in the throw from lock-to-lock, the steering bar presented a problem with alignment. Where a regular wheel does not have to come back to the exact position for midships rudder, a steering bar definitely must.

Another engineering challenge was that there were no off-the-shelf solutions for controlling the thrust by twist grip. We found that some motorcycle-style throttle controls did not last very long in the marine environment. It became necessary to develop military-grade components that would be reliable. Fully electronic "drive-by-wire" control was the obvious way forward, but the sensors in the twist grip would have to withstand not only the challenges of the seawater but also shocks, vibration, and rough treatment by users subjected to mental and physical stress.

In one early installation the delay between a given manual input and subsequent shift and throttle actuation was more than a full second. Plus the controls were not fully intuitive. This combination was enough to give test operators the impression that the system had a mind of its own. The test RIB (rigid inflatable boat) climbed up on the floating dock and then backed down with such determination that it reversed full speed into a big lifeboat moored nearby. Even though neither boat showed any signs of damage from the impact, the system was obviously not ready for production.

With refinement the bugs were worked out and the controls became responsive. On the first single-drivetrain boats it was evident that the systems increased maneuvering precision in tasks such as picking up floating buoys, boarding, and docking. We were gratified to see novice operators,

Above—*A new, fully electronic steering bar outfitted on a third-generation 8m (26.2') RIB for the Swedish Coast Guard. It and the Swedish Sea Rescue Society were the first agencies to adopt the nascent steering system 15 years ago.*

Below—*In a joint venture, a Norsafe 850 Magnum, fitted with twin 300-hp (224-kW) Volvo Penta D4s, tested the latest drive-by-wire system built to control twin drivetrains in two different modes: single handle and dual handle.* ***Left***—*The newest prototype of the Ullman steering bar, foreground, is installed side-by-side with a conventional helm station, background, for comparative testing.*

who were still challenged by conventional wheel-and-lever controls, docking the test boat intuitively as though it was a small car.

Our next development challenge, which very well could have been a deal killer, was cultural, not technical. The most-seasoned experts in any field are rarely the first to embrace new technologies; however, they are the ones asked to evaluate them. Their resistance to change is not a human flaw; it's quite natural to apply your own experience as a frame of reference for comparison. The greater that experience, the more invested you are in the conventional technology.

Growing up, I was a fairly competent downhill skier, so I had mixed feelings about the development of the new carving skis that made learning so much faster than anything we could have dreamed of in the 1960s. Many novice skiers now came out on even the steepest slopes. Eventually I tried the new skis and realized that even though my old skills were still useful, the combination just made skiing better, faster, safer, and more fun.

Back to the steering system. First to try it out were the Swedish Coast Guard and the Swedish Sea Rescue Society. Both agencies had seen increasing numbers of injuries among their crews and sought means of preventing them. We fitted 7.5m and 8m (24′7″ and 26′3″) single waterjet boats with the handlebars. There was much initial skepticism, but with encouragement from command, and experience with the new technology on the water, the operators' resistance soon vanished. Both organizations have since adopted the steering bar system in combination with jockey-style suspension seats as standard equipment on their respective fleets of smaller waterjet boats.

Next Development

A steering bar system for twin drivetrains is much more complicated to build, and to make safe and reliable enough to handle larger platforms and more powerful drivetrains, than a single drivetrain system. In a joint R&D project of Volvo Penta, Ullman Dynamics, and Norsafe, a new platform has been built to demonstrate and prove the new fully electronic, drive-by-wire steering bar/control system built for twin drivetrains. It has been installed on a Norsafe 850 (8.9m/29.1′) Magnum powered by twin Volvo Penta D4-300 diesels and DPH drives for testing.

The steering system allows changing between single-handle mode, where both drivetrains including forward and reverse gears and thrust are synchronized and operated by one hand, and dual-handle mode, where each drivetrain is operated independently with each hand. Dual mode is intended for low-speed maneuvering like boarding, stern ramp retrieval, and docking; it offers few advantages at high speed.

Work is ongoing to verify different versions of the system, built for different propulsion systems such as twin waterjets, outboards, and multiple drivetrains. PBB

About the Author: *Johan Ullman is a navy officer, medical doctor, and scientist, focusing on trauma from whole-body impact at sea. He founded Ullman Dynamics, a manufacturer of high-impact suspension seats, and started the High-Speed Boat Operations Forum, a biennial gathering of marine professionals who research the impacts of working in extreme ocean environments.*