Variable Marine Jet Propulsion

"For the Next Generation of Tactical Applications."

Jeff Jordan
President
Intellijet Marine, Inc.

What If . . .

What if your car had only one gear?

- It would work like a Model “T” . . .
  . . . or like a boat.

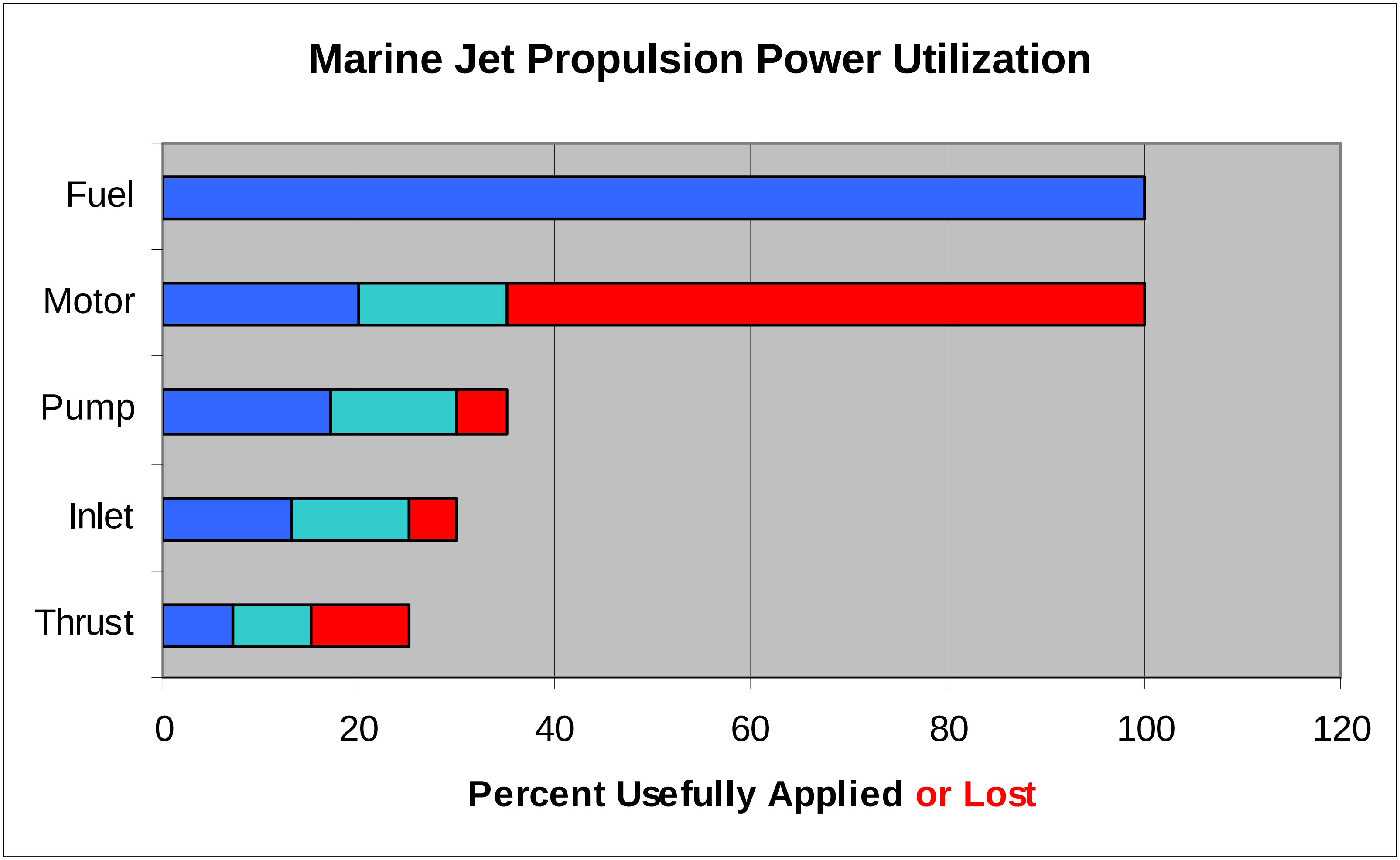
- You couldn’t change gears to operate more efficiently at lower speeds or when you had a greater load.

- You couldn’t use a computer to shift for minimum fuel use.

Tactical Requirements

- High-speed capable
- Heavy load capable
- Maneuverable at all speeds
  - Docking
  - Landing
- Shallow draft
- Fuel efficient – minimum power lost

Power Lost


Marine Jet Propulsion Power Utilization
Fuel
Motor
Pump
Inlet
Thrust
0
20
40
60
80
100
120
Percent Usefully Applied or Lost

Causes of Lost Power

- Motor runs lightly loaded – as in low gear.
- Flow through pump is too high/low.
- Water enters inlet too fast/slow.
- Water leaves nozzle too fast/slow.

Each Power Loss is Final

- Pump can’t save power lost in motor.
- Pump must make up inlet loss.
- Nozzle velocity divides power to
  - Propel the vessel.
  - Propel the jet – more or less lost power.

High Propulsion Efficiency Requires

- ✓ High Motor Efficiency
- ✓ High Pump Efficiency
- ✓ High Inlet Efficiency
- ✓ High Fluid Power Transfer Efficiency
- ✓ All at the same time
- ✓ Over the operating speed range
- ✓ Over the operational load range

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The Question is . . .

How much thrust do you get out of the fuel power input?

Now . . .
Imagine a boat
that works like your car.

Where computers control
the motor and transmission,
so the system operates at peak efficiency
over wide ranges of acceleration,
speed, and load.

Load Carrying

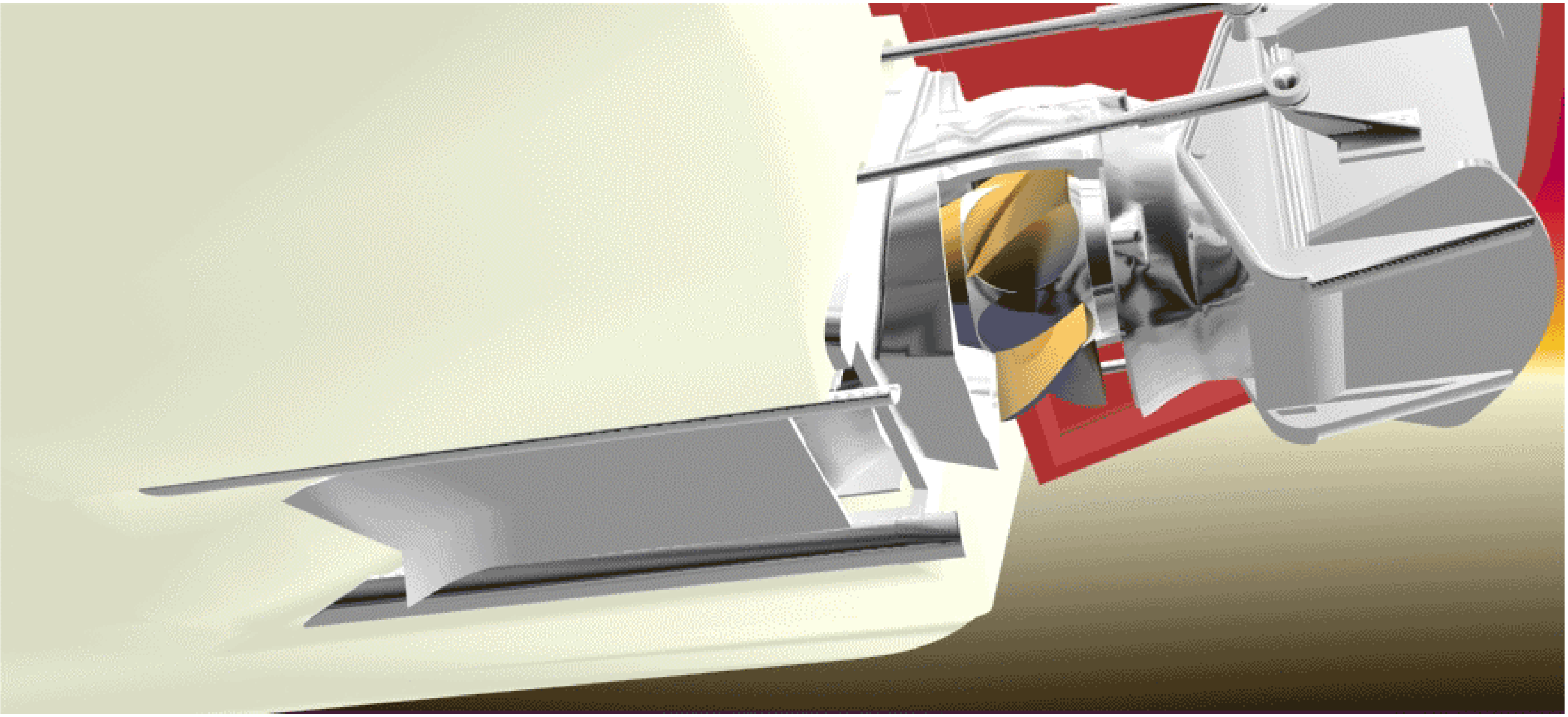
System Design Objectives

- Operate the motor efficiently
- Maintain pump efficiency
- Maintain inlet efficiency
- Vary nozzle size for best power transfer
  - Large nozzle at low speeds
  - Smaller nozzle at higher speeds

Variable Marine Jet Propulsion

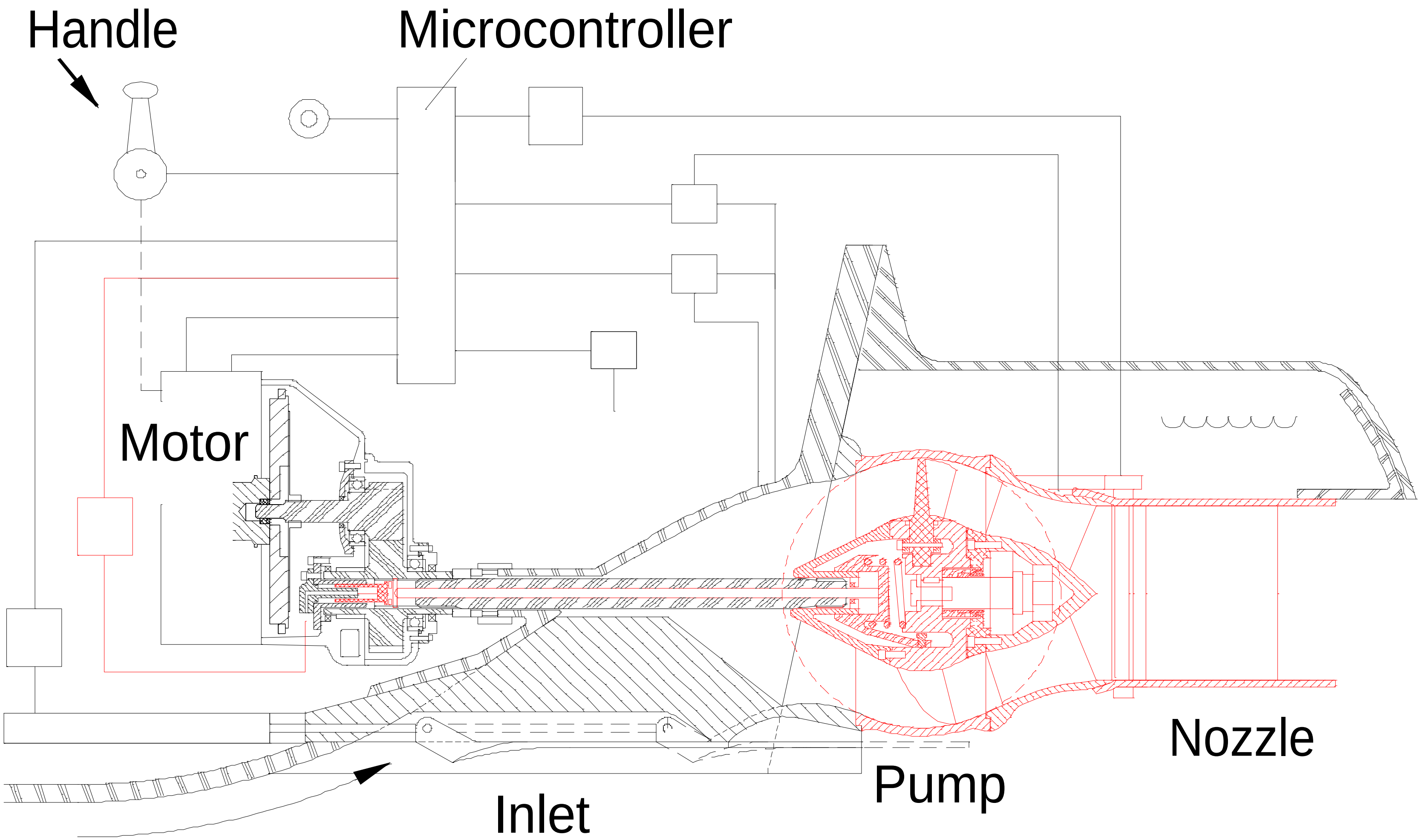
- Second-generation system.
- Adds variable-pitch spherical pump.
- Has lower jet velocity at low water craft speed.
- Retains variable rectangular nozzle.
- Incorporates embedded microcontroller.

Virtual Reality Model



Variable Marine Jet Components

- **Variable-pitch propeller pump**
- **Variable rectangular steering nozzle**
- **Variable inlet duct**
- **Common embedded microcontroller**


Handle
Microcontroller
Motor
Nozzle
Pump
Inlet

Variable-pitch Propeller Pump

- Spherical design provides 90° fitted vane rotation
  - Efficient variable propulsion
  - True neutral at zero pitch
  - Reverse pitch for reverse thrust
  - Eliminates need for reversing “bucket”
- Quick, smooth shifting forward/neutral/reverse
- Continuously Variable Power Transmission

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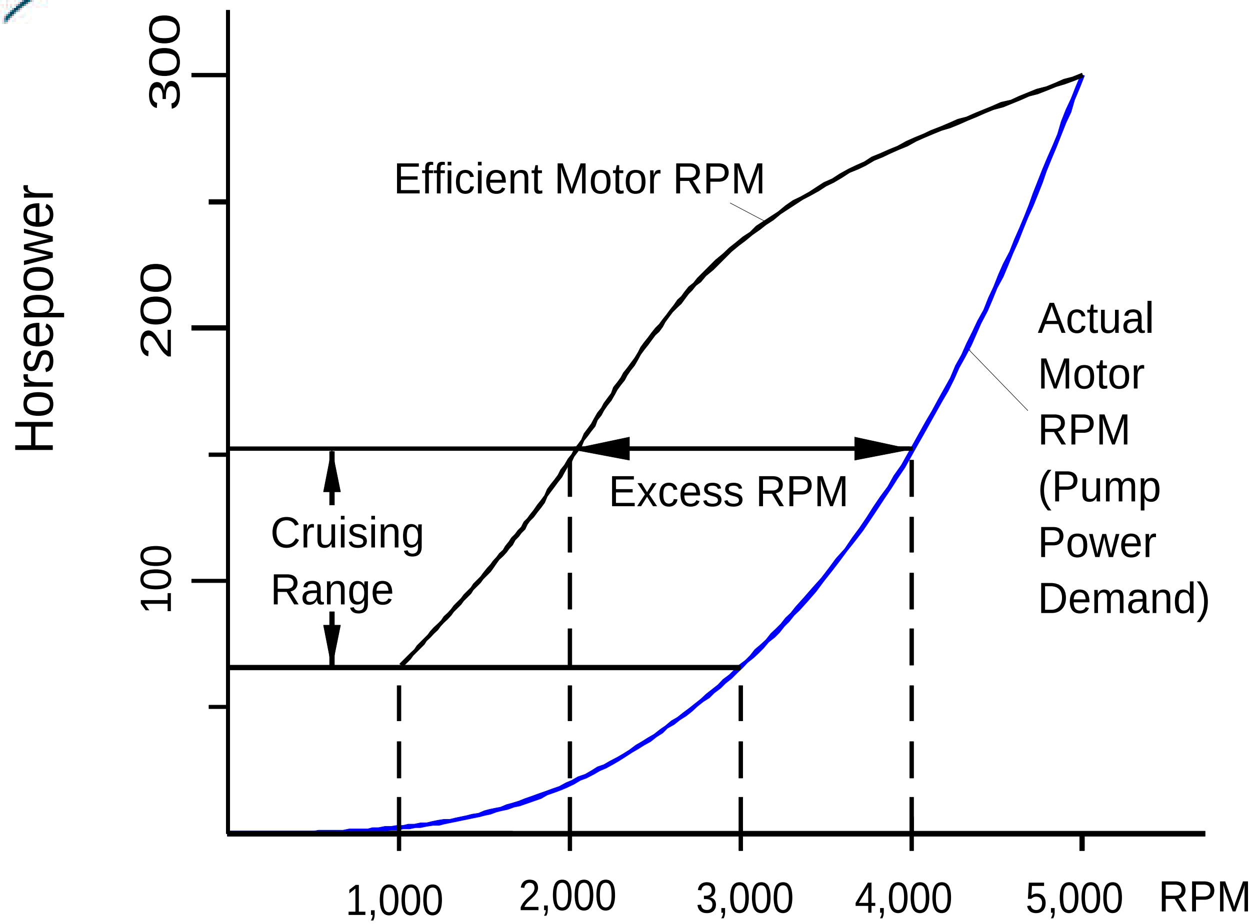
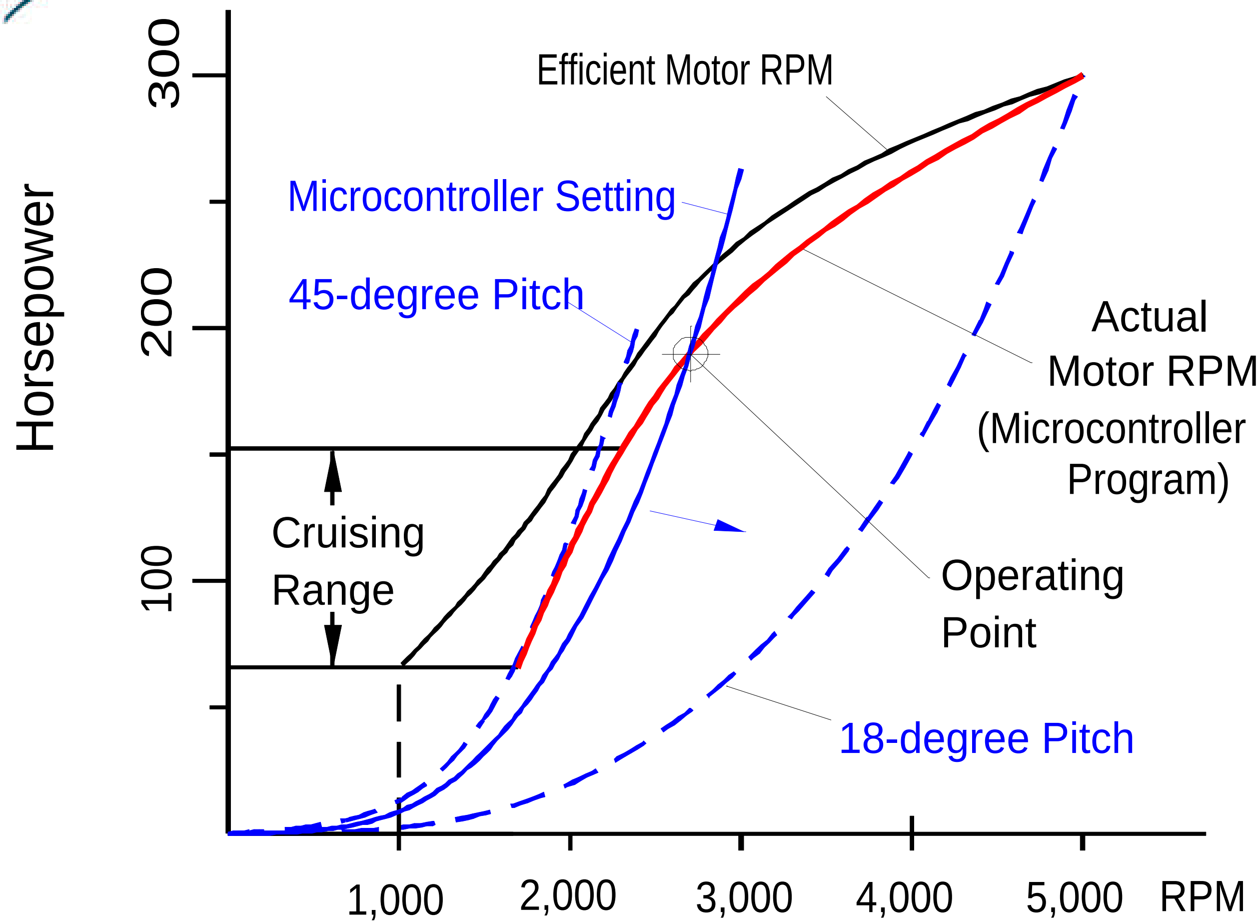


Conventional Jet Power Transmission



Continuously Variable Power Transmission

Variable Marine Jet Components

- **Variable-pitch propeller pump**
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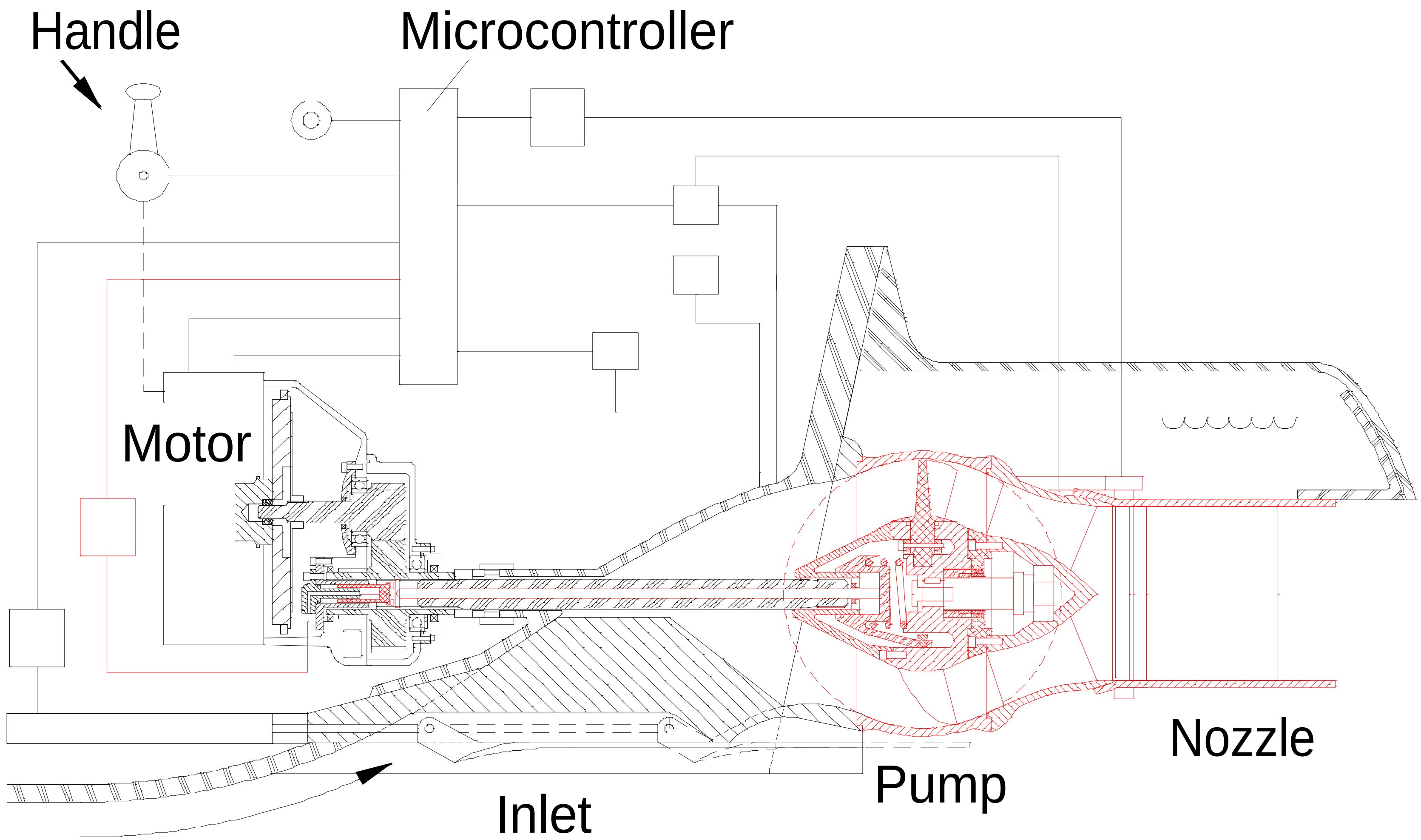


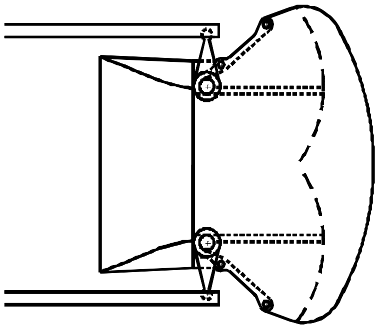
Variable Rectangular Steering Nozzle

- Embedded microcontroller maintains efficient pump operation by adjusting nozzle area.
- Provides steering in both forward and reverse.
- Allows elimination of reversing bucket.
- Steering demo in following video clip.

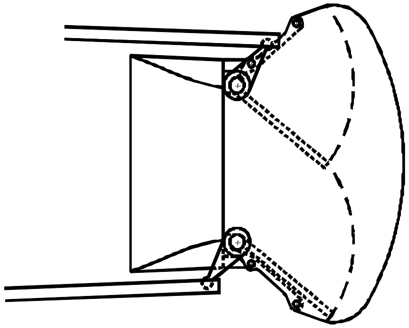
Maneuverability

Variable Nozzle Functions

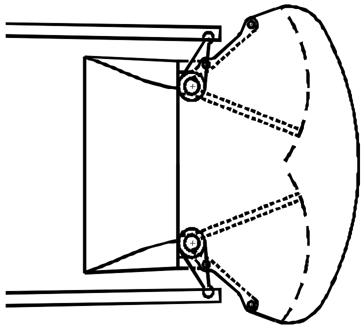
Low-speed operation



Tight turn



High-speed operation



Variable Marine Jet Components

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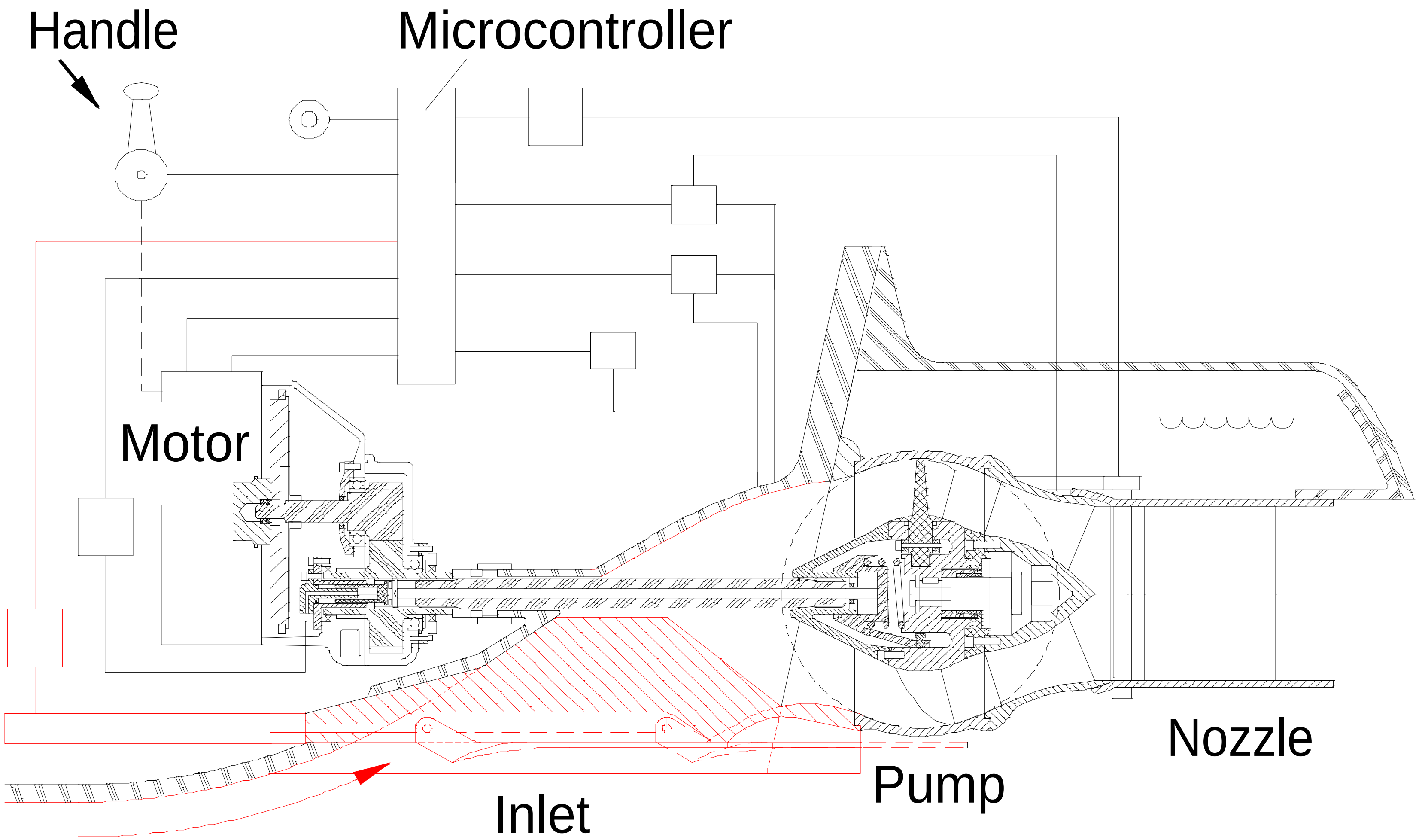
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Variable Inlet Duct Functions

- Slide adjusts entrance opening for ideal velocity.
- Flow cross section area increases gradually along flow.
- Flow velocity is reduced, pressure increased by
- Bernoulli's Principle ($p + V^2/2g$ is constant)
- Inlet duct becomes nozzle in reverse thrust mode

Variable Marine Jet Components

- **Variable-pitch propeller pump**
- **Variable rectangular steering nozzle**
- **Variable inlet duct**
- **Common embedded controller**

Common Microcontroller

- Reads RPM, speed and duct pressures
- Adjusts pump for most efficient motor operation
- Adjusts nozzle to maintain pump efficiency
- Adjusts inlet for efficient recovery of total dynamic head IAW Bernoulli's Principle

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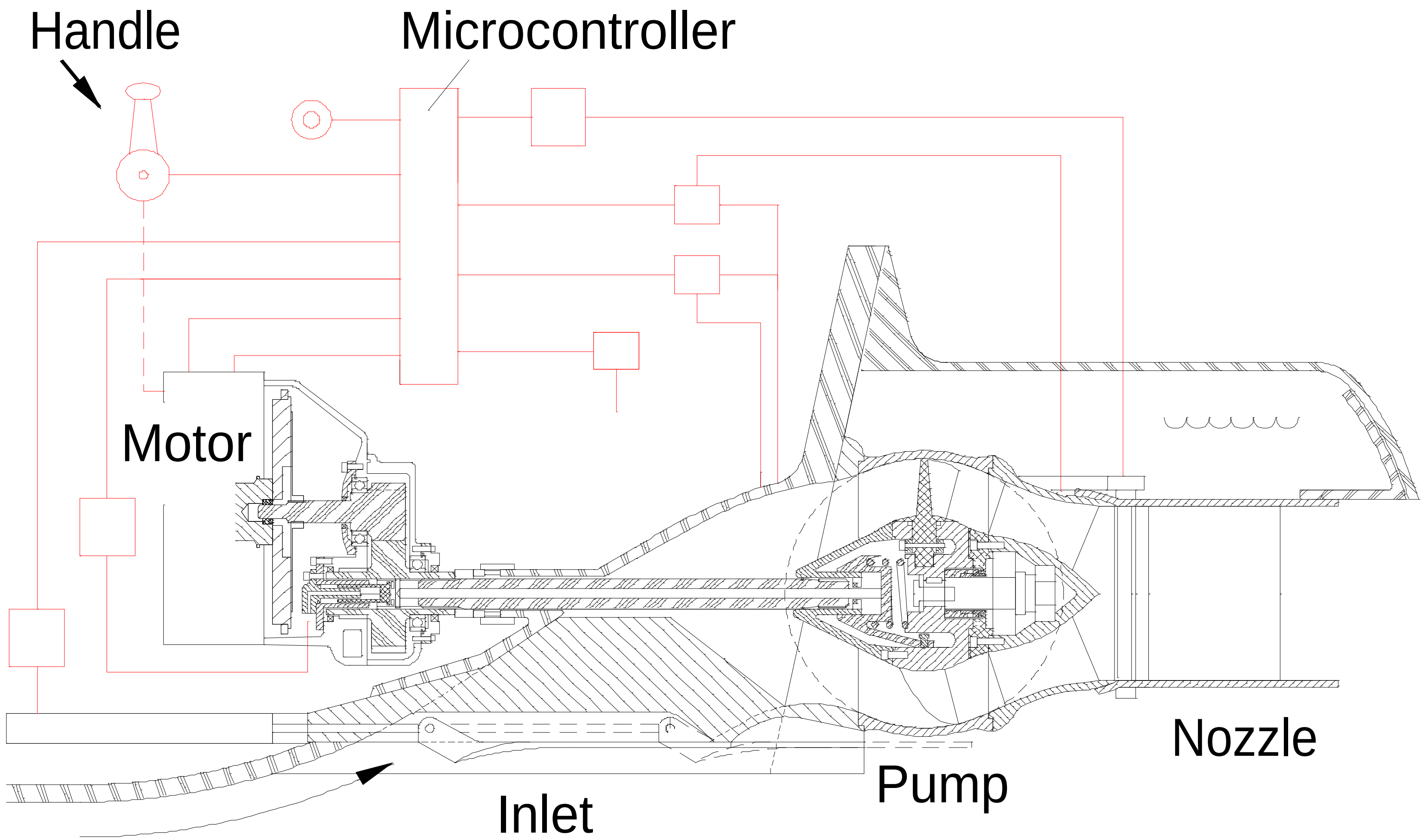
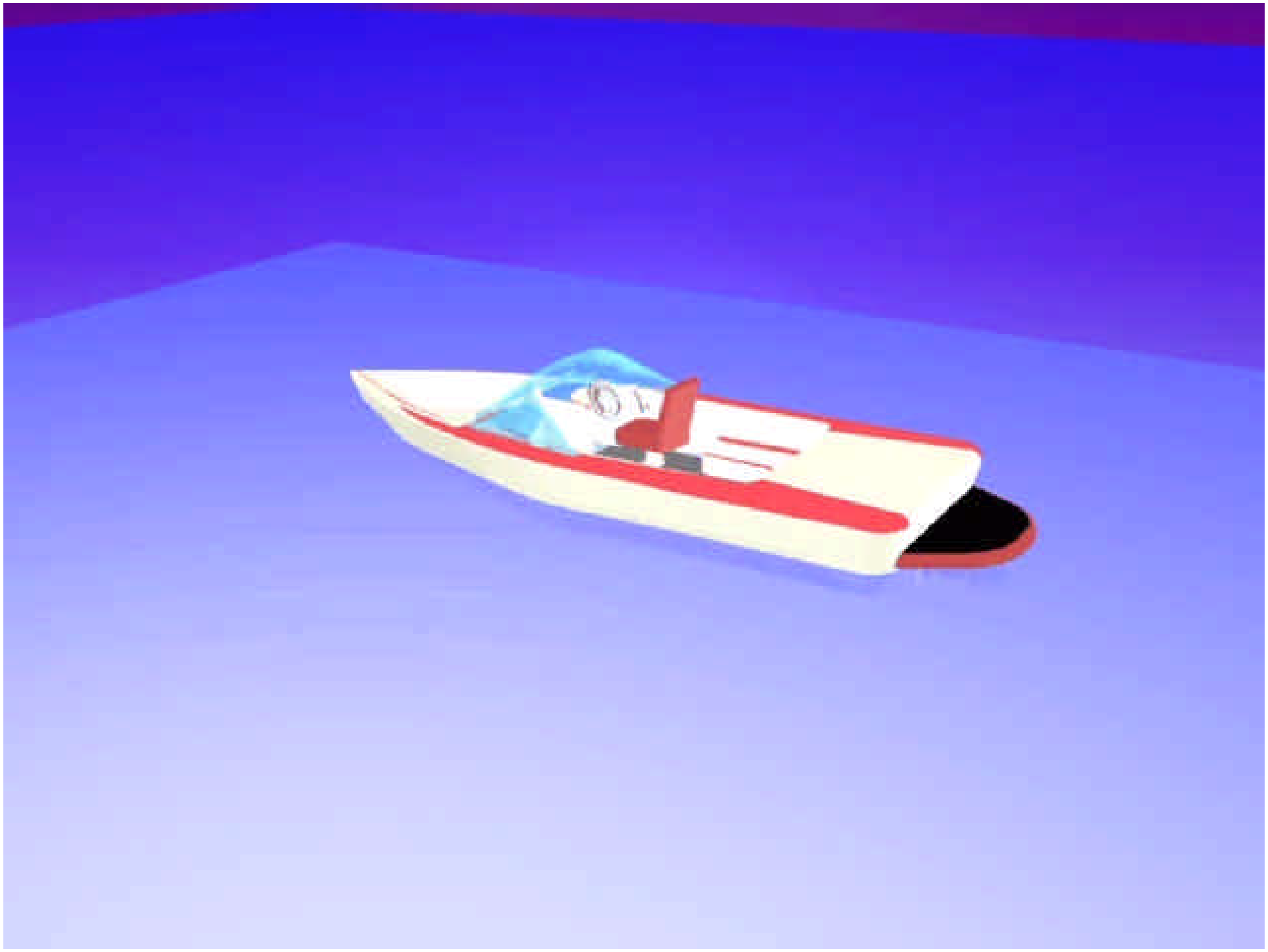


Orientation



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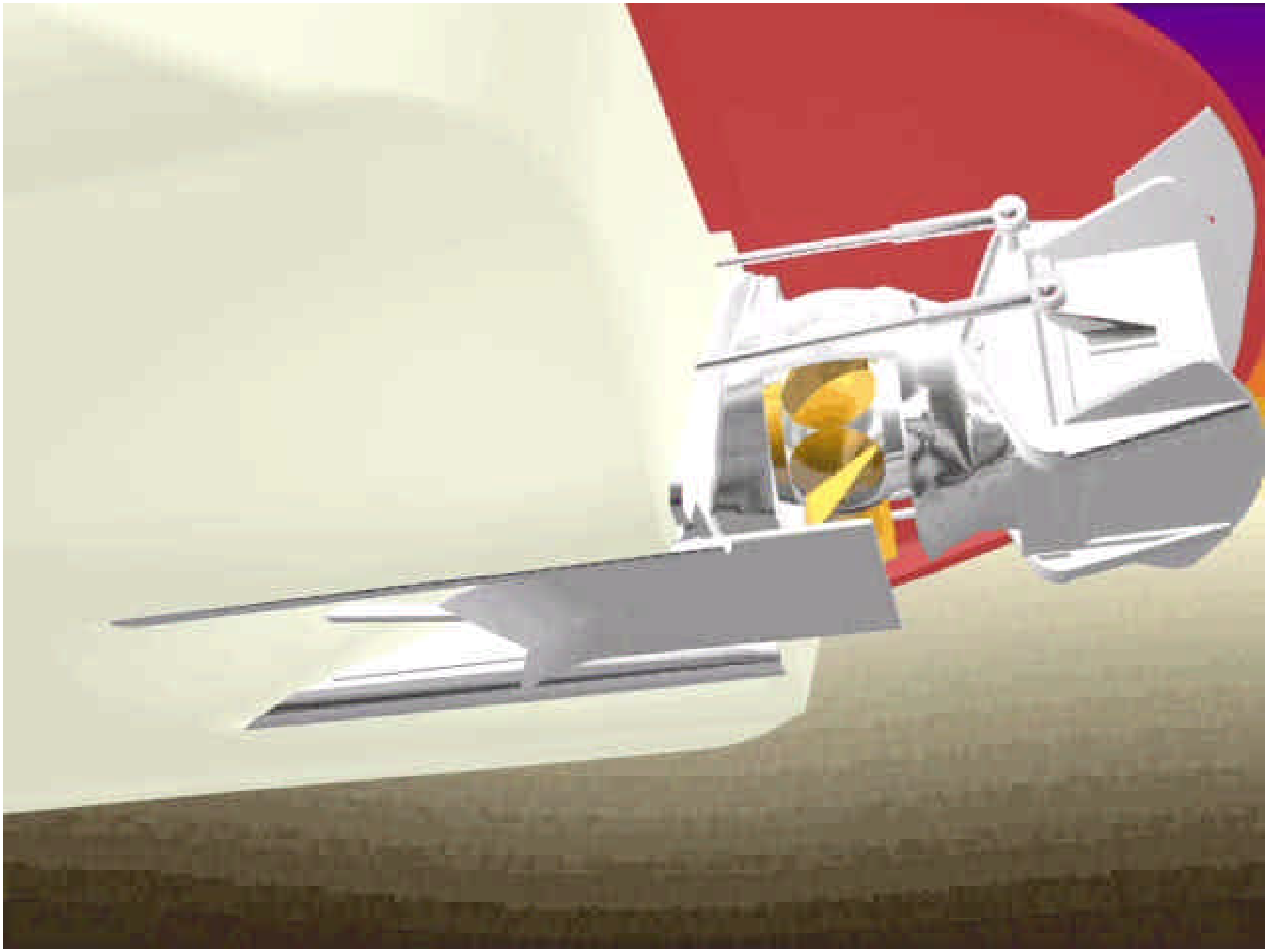
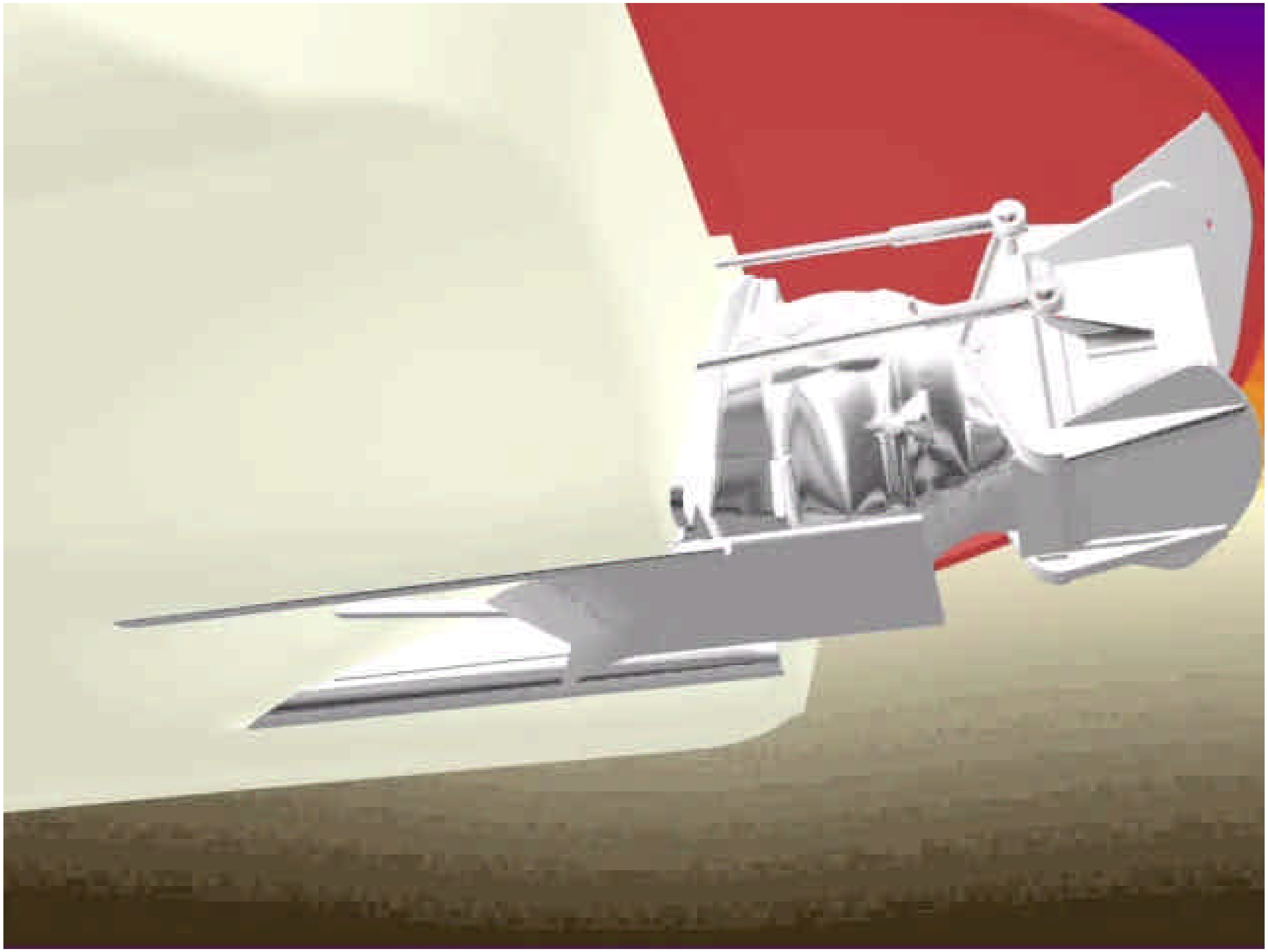
Pump Action



Nozzle Functions

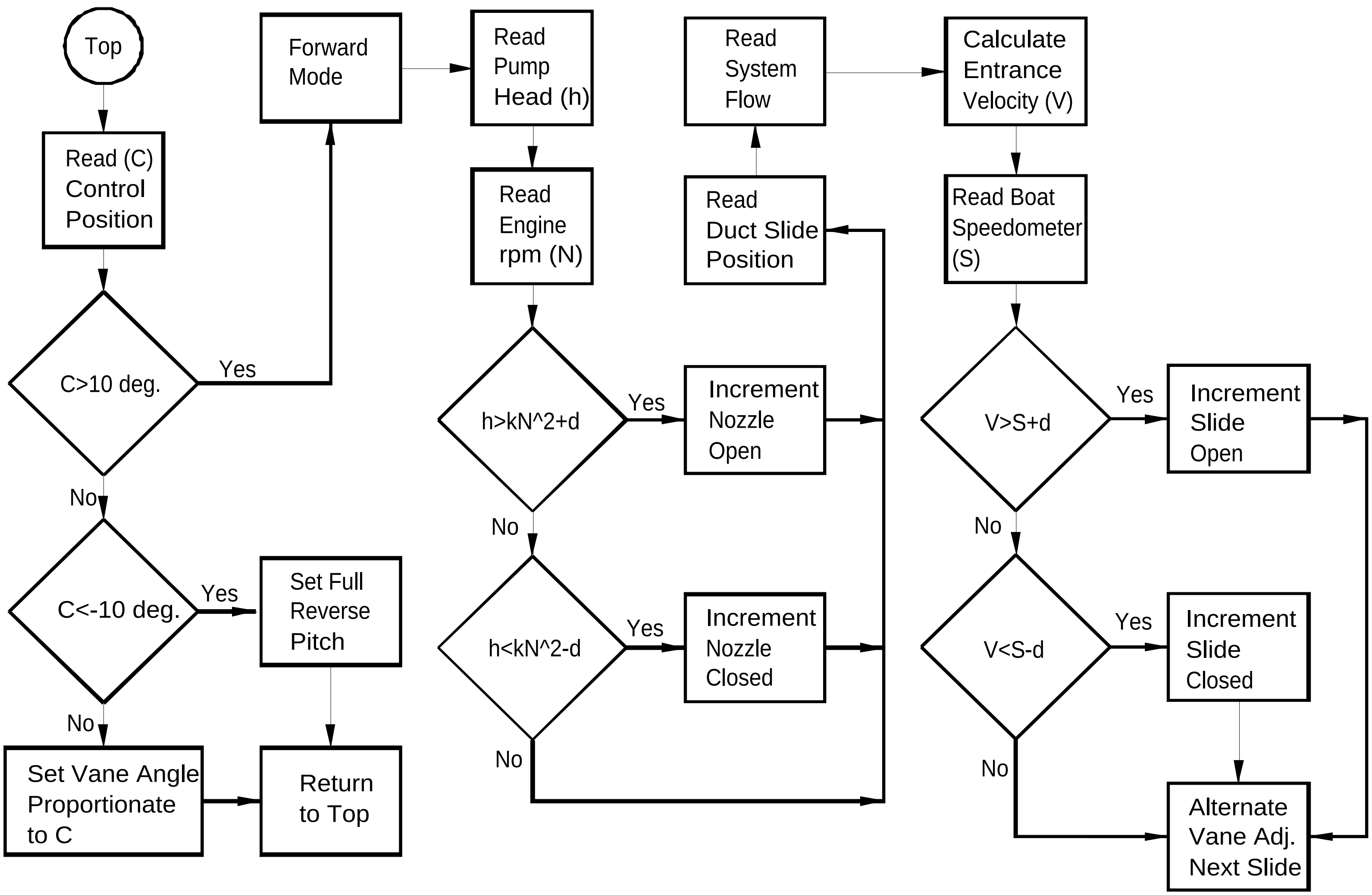


Microcontroller Programs

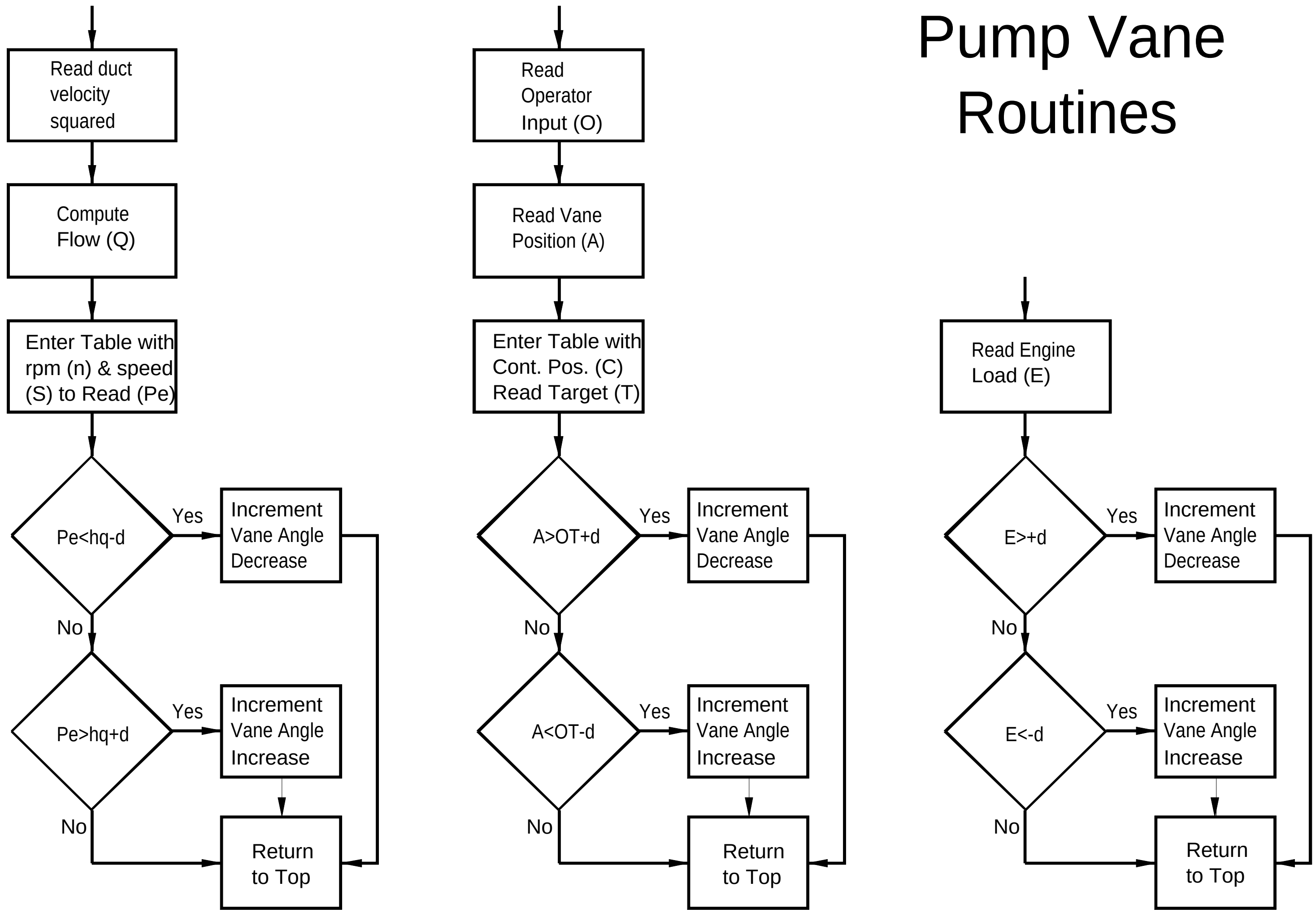
- Rudimentary flow diagrams on following slides
- Still go beyond this discussion
- Artificial intelligence likely in actual applications
- Standard integrated control systems interface

- ***Fly-by-wire for watercraft***

Control Schematic



Pump Vane Routines



Summary

The embedded microcontroller program regulates

- **The pump to maintain motor efficiency.**
- **The nozzle to maintain pump efficiency.**
- **The inlet to maintain recovery efficiency.**

So the total system operates at peak efficiency at all speeds and under all loads and accelerations.

Natural Consequences of the Control Scheme

- **Jet size is reduced with boat speed**
  - 12” at low speeds
  - 6” at top speed

- **Inlet reduces velocity 60% to 80% at top speed**
  - Propeller always operates in efficient range
  - Higher pressure suppresses cavitation noise

Stealth Consequences

- Cavitation suppressed at operating speeds
- Jet velocity is low relative to the wake
  - No rooster tail
  - Reduced wake luminescence
  - Reduced noise

The Operator Experience

- Familiar single-handle control
- Shift quickly without reducing RPM
- Quick steering response
- Multiple program selection – set it & forget it modes
  - Maximum performance when detection is unavoidable
  - Suppress Cavitation Noise when avoiding detection
  - Maximum fuel economy for cruising

Tactical Requirements

- High-speed capable
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- Maneuverable at all speeds
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- Fuel efficient – minimum power lost

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“Tactical Versatility”

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