Exploring the Deep With SONIA

Félix Pageau, Team Leader
Martin Morissette, Software Team Leader

SONIA AUV Project
École de Technologie Supérieure
http://sonia.etsmtl.ca

TS-1990

SONIA

Java™ Platform Powered Autonomous Underwater Vehicle

Learn how a team of undergraduate engineering students used Java™ technologies to build a winning Autonomous Underwater Vehicle platform

Agenda

Overview of SONIA AUV

System, Mechanical and Electronic Design

Software Architecture

Test and Debugging Tools

Demo of the 3D AUV Simulator

Development Methodologies

Conclusion

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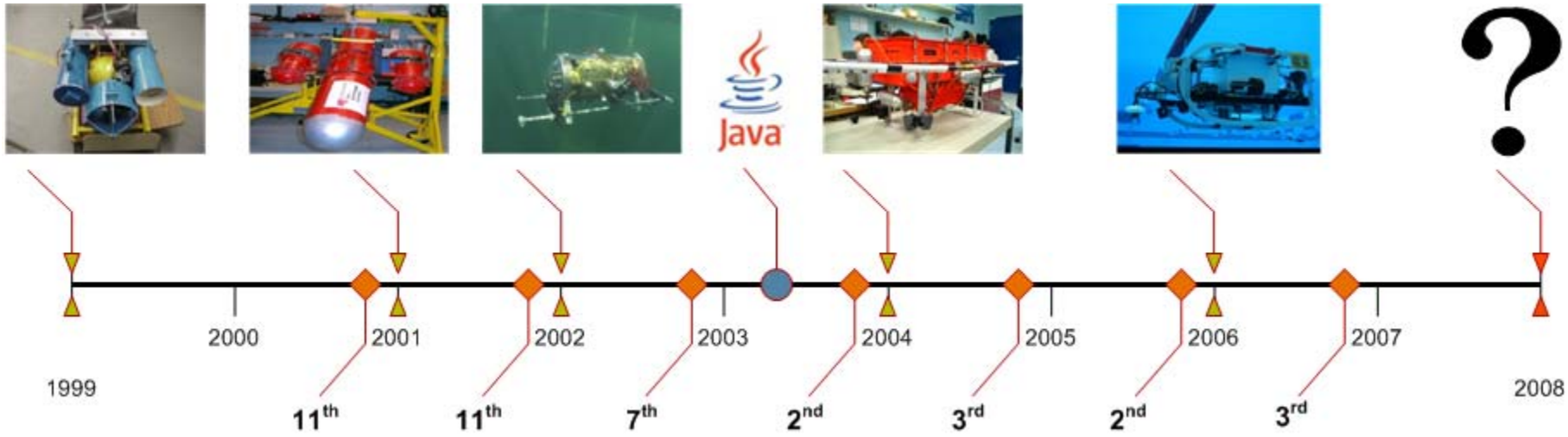
SONIA AUV Project

"**S**ystème d'**O**pération **N**autique **I**ntelligent et **A**utonome"

- Founded in 1999
- Entirely managed by volunteer undergraduates
- Team of ~30 engineering undergrad students
- Low-budget project



SONIA AUV Project

“**S**ystème d’**O**pération **N**autique **I**ntelligent et **A**utonome”

SONIA 2006 competition team

École de Technologie Supérieure

Overview of the University

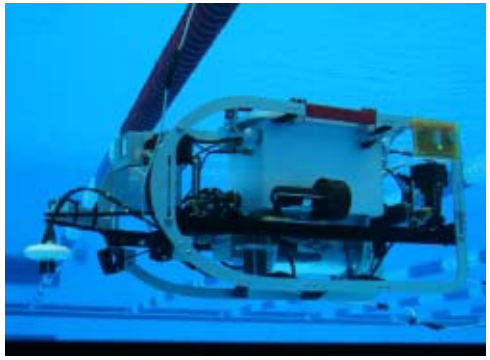
- 4th largest engineering university in Canada
- 5000 undergraduate and graduate students
- Applied engineering faculty of the Université du Québec network
- 4-year, 120 credit co-op engineering program
- Only admits professionally trained technicians
- Official language: French

Source: École de technologie supérieure. 2007. *Bilan et perspectives*. <http://www.etsmtl.ca/manager/doc/images/2007-01-25-commissioneducation.pdf>

Autonomous Underwater Vehicle

What is an AUV

- Sensors based underwater navigation
- Controlled by Artificial Intelligence (AI)
- Interacts with its environment
- AUVs are **NOT** remotely operated



AUVSI and ONR's International AUV Competition

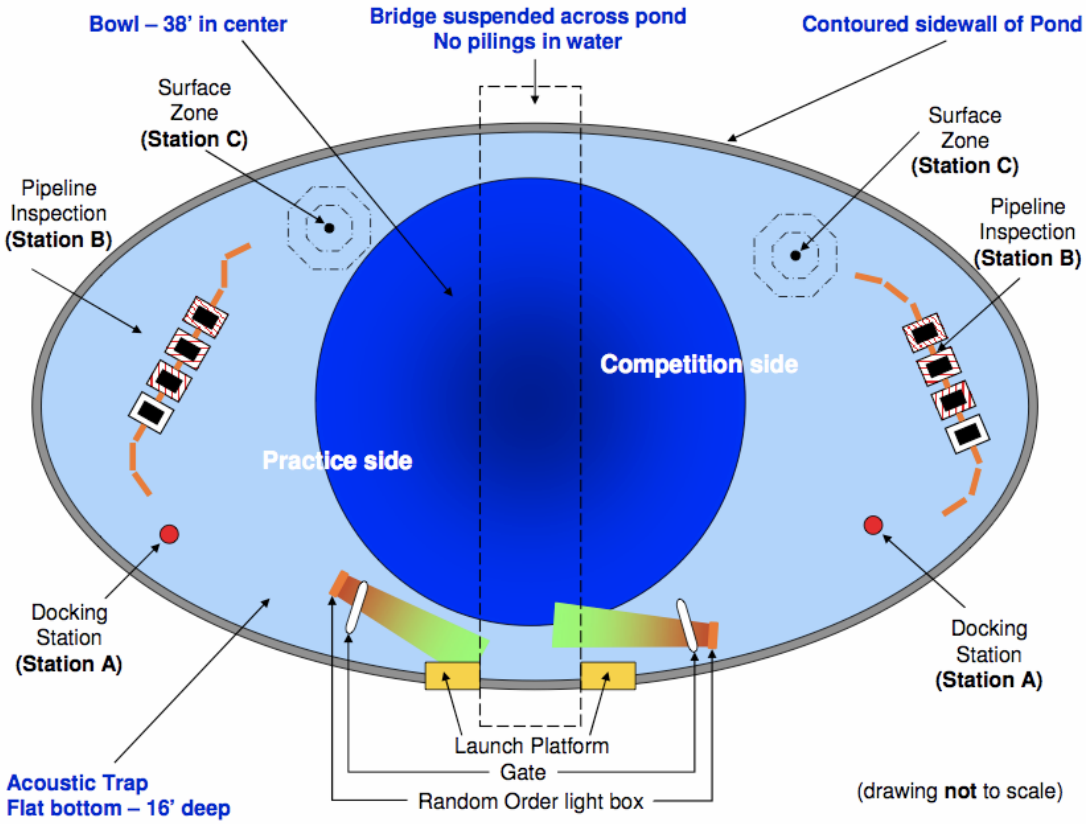
Overview of the Competition

- Held at SPAWAR System Center San Diego, CA
- Focus on autonomous operations
- Annual competition
- Teams from Canada, India, Japan, USA…

Source: SPAWAR System Center San Diego. 2002. *Transducer Evaluation Center*. <http://www.spawar.navy.mil/sandiego/facilities/jpg/transdec.jpg>

AUVSI and ONR's International AUV Competition

2006 Mission



Source: AUVSI. 2006. *Official Rules and Mission*. <http://www.auvsi.org/competitions/Rules_Mission_Final_2006.pdf>

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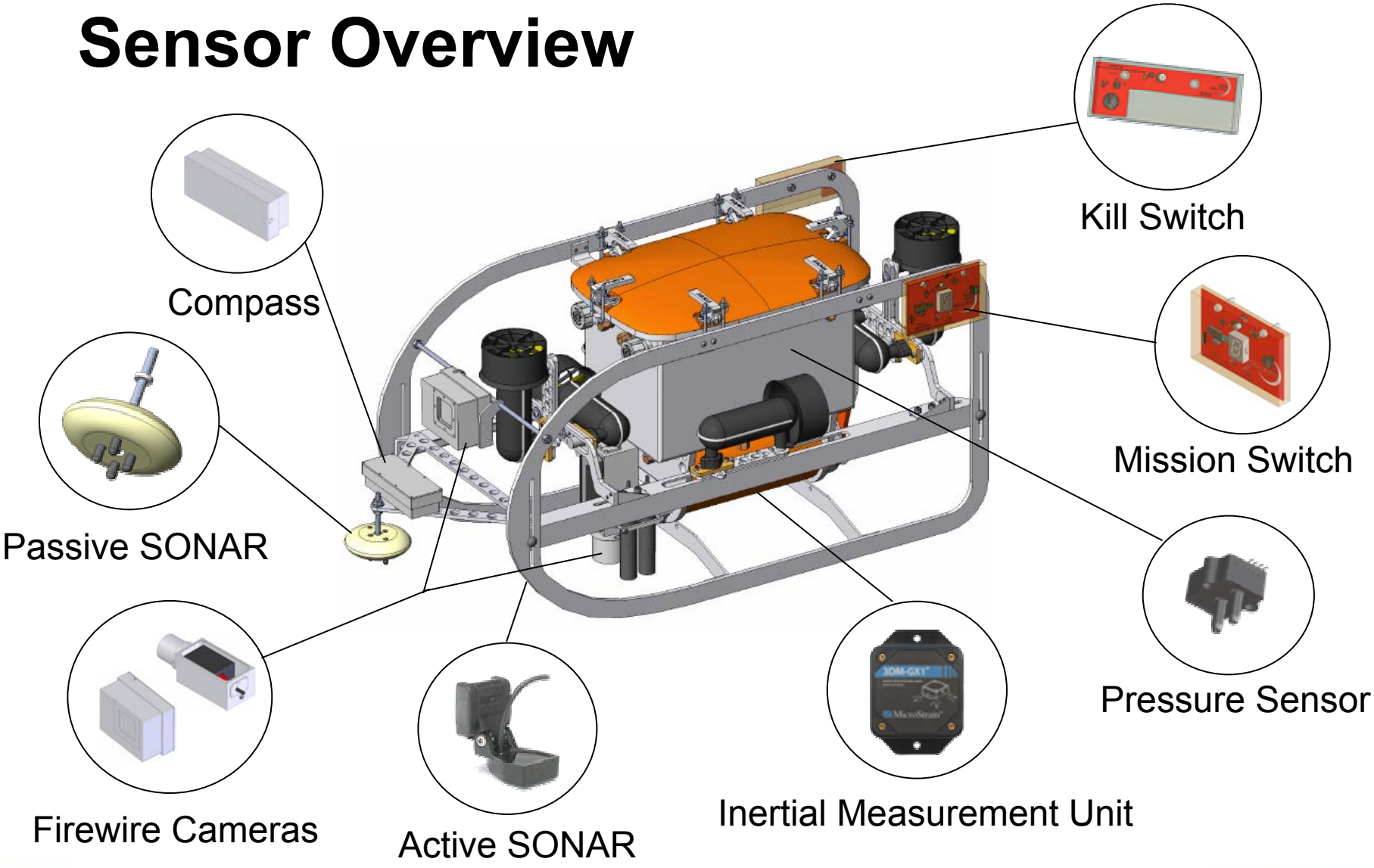
SONIA AUV System Design

- Watertight
- Neutral buoyancy (+ 0.5 %)
- Battery operated
- Shallow water operations
- Four degrees of freedom (heave, sway, surge, yaw)
- Mass inferior to 25 kg
- Rapid deployment
- Easy access to electronic components

Sensor Overview



DEMO

3D Vehicle Design

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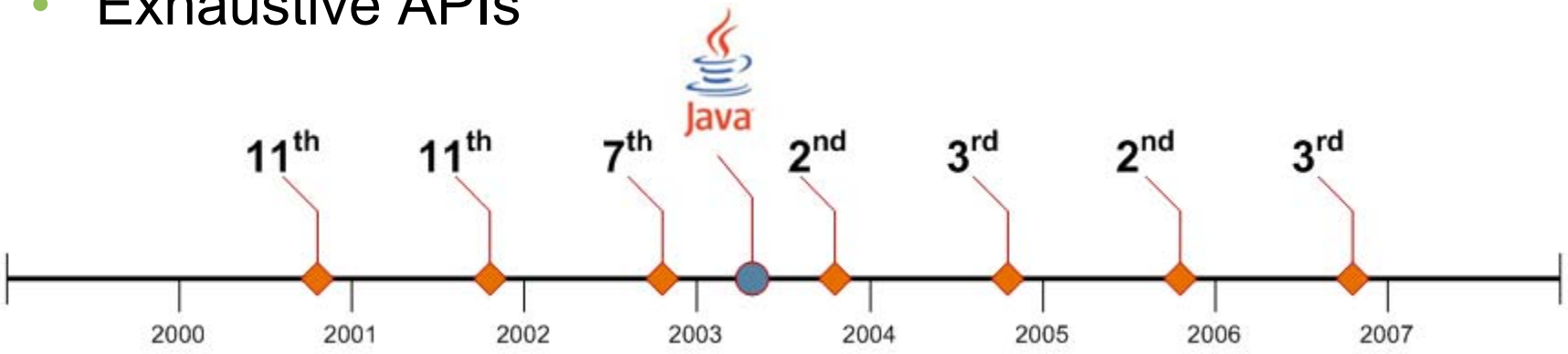
Switch from C/C++ to Java Platform

Reasons for the Switch

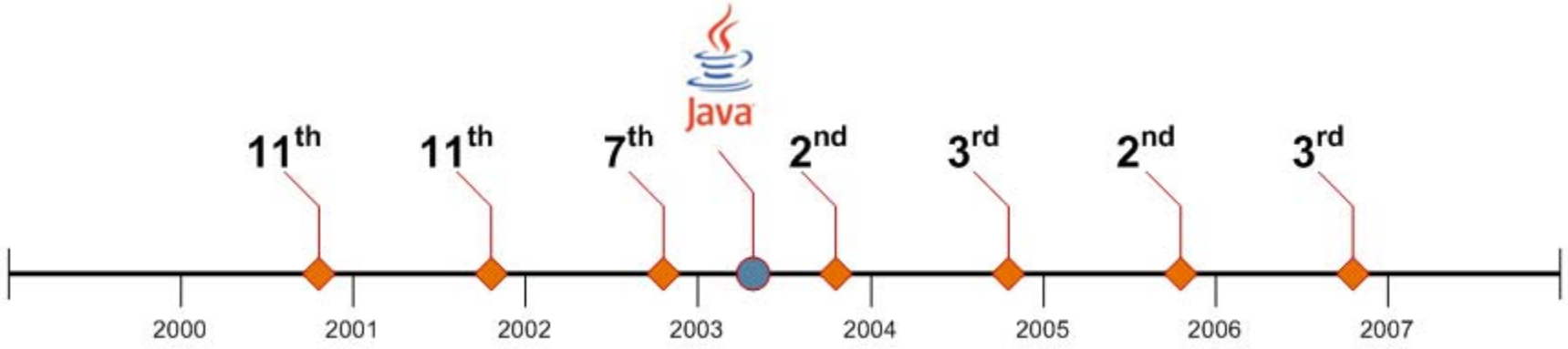
- Widespread OO language amongst undergrads
- Platform independent (Linux, Windows, Mac OS X)
- Open source tool availability
- Checked exceptions
- Pervasive memory protection
- Exhaustive APIs



Switch from C/C++ to Java Platform

Impacts of the Switch

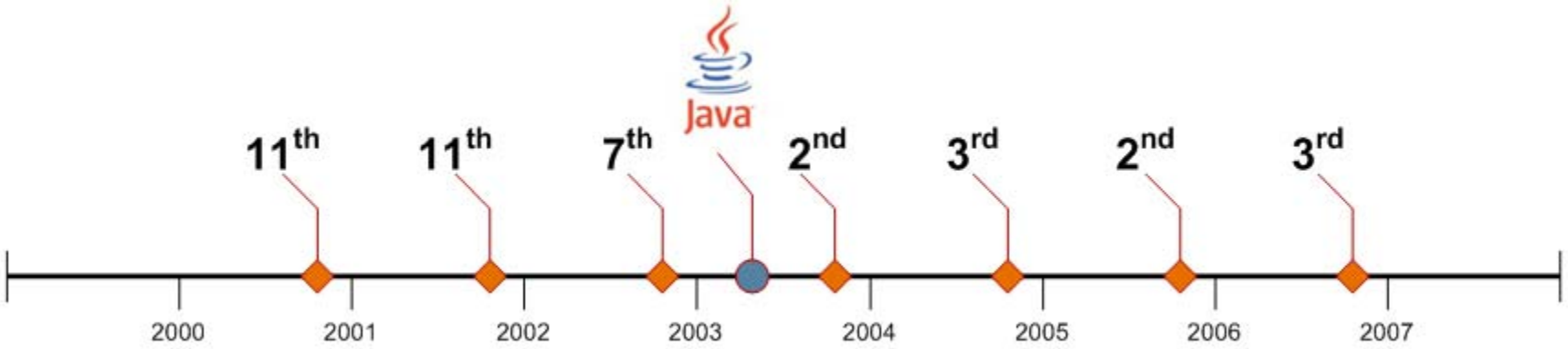
- Faster development: designed from scratch an improved system within one year
- Maintainability: same version since the switch throughout many generations of developers
- Scalability: support for new devices, new communication protocols, etc.



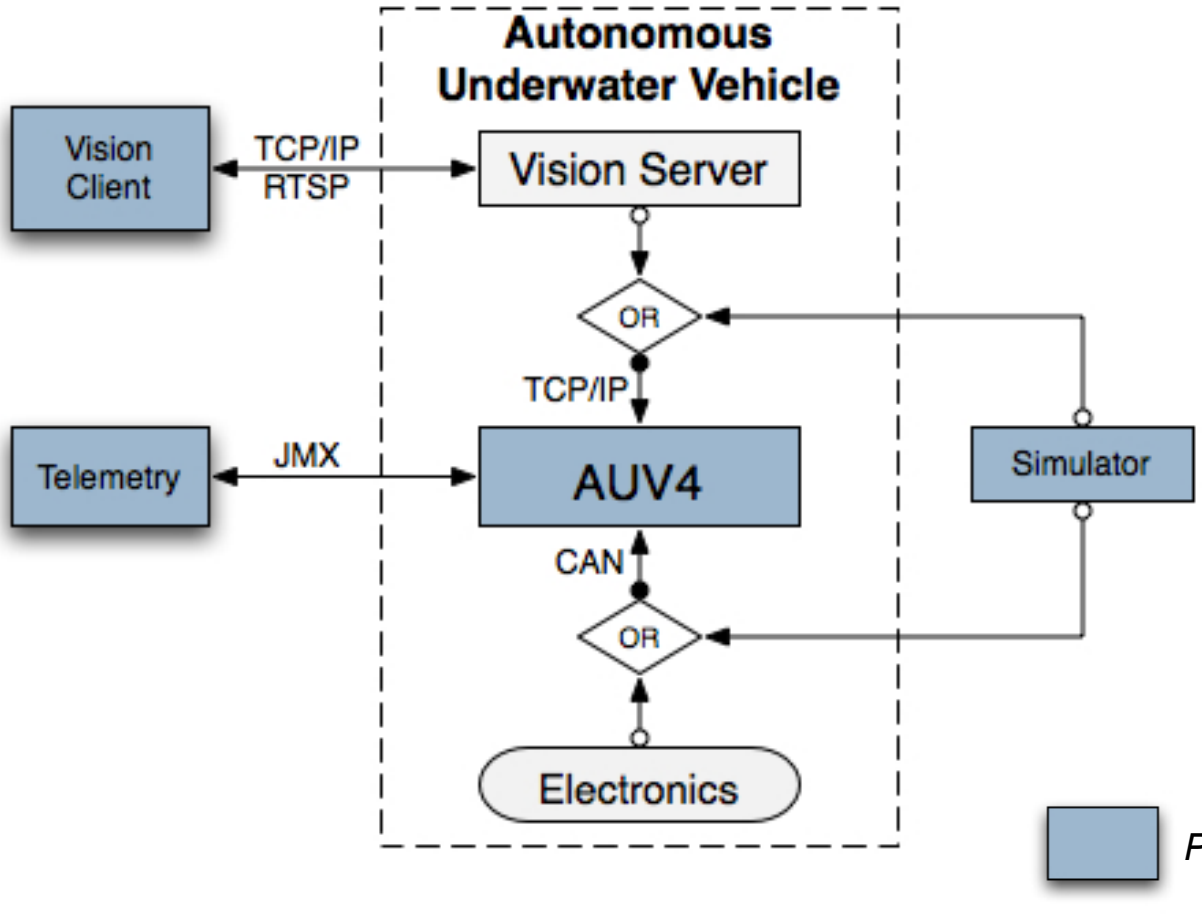
Java Technology in Robotics

How to Integrate Java Technology

- Memory allocation at startup
- Limit dynamic instantiation
- Modular design with intelligent devices
- Profiling of critical modules
- Object pooling, recycling used objects

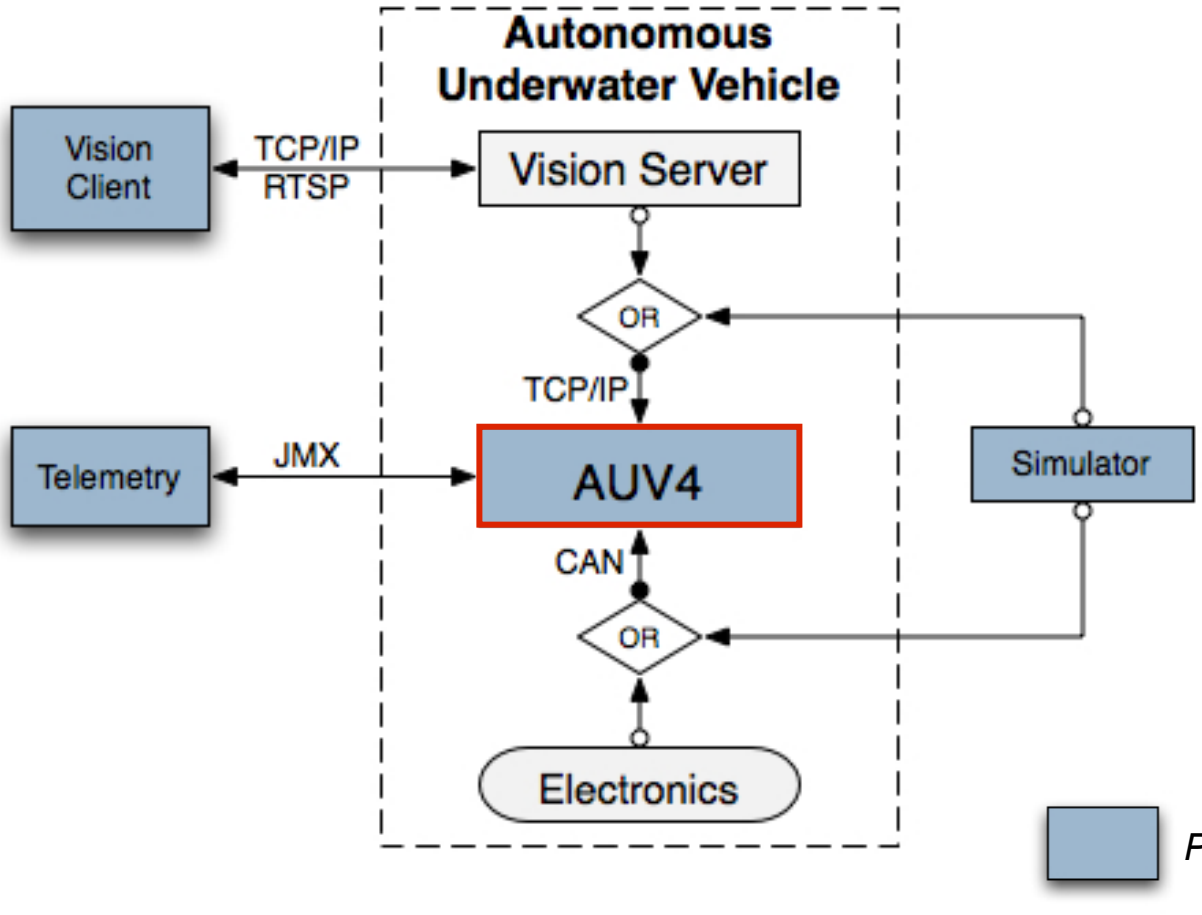


Software Architecture



JMX™ = Java Management Extensions specification

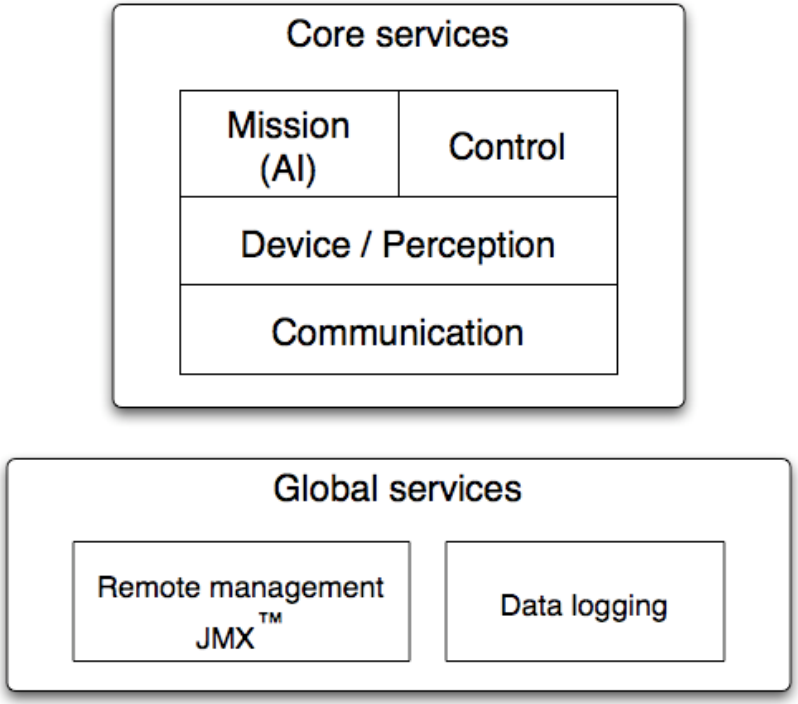
Software Architecture



AUV4

Capabilities

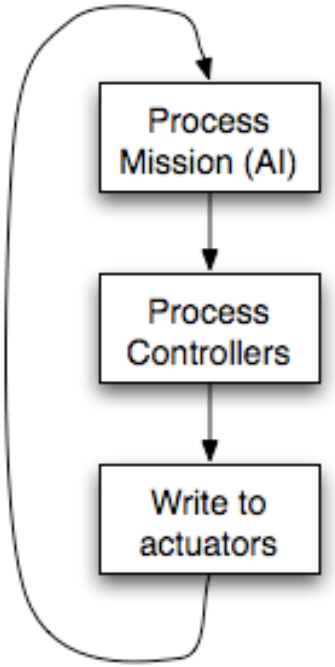
- Sensor interface
- Data fusion
- Navigation and control
- Decision taking
- Artificial intelligence
- Data logging



AUV4 Architecture

Control Loop

- Navigation decisions taken within a single thread (loop)
  - Synchronized with actual navigation sensors
  - Deterministic execution of tasks
  - Processing over a same timeframe sensor value set
  - Simplify overall system
  - Prioritize navigation over global services



AUV4 Architecture

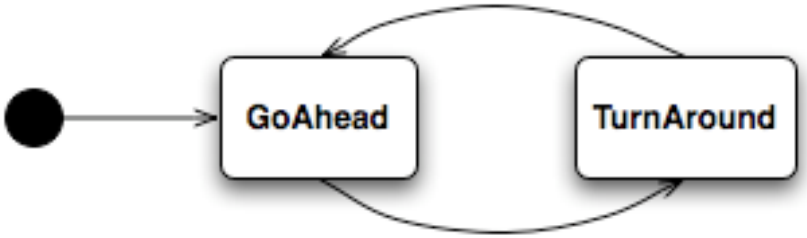
Control Loop

```
public void run() {
    markBeginning();                    //Mark the beginning of an iteration

    applyNextDeviceValue();             //Baseline the values for determinism
    this.refreshSelfEnclosedDevices();  //Process polling based devices

    supervisor.process();               //Check for warning conditions
    mission.process();                  //Process AI
    controllerManager.process();        //Process navigation controllers
    commControlProcess.process();       //Process Tx communication

    markEnd();                          //Mark the end of an iteration
    displayStats();                     //Display stats (incl. overrun detection)
}
```

AUV4 Architecture

Mission

- Simple state machine
- Advanced AI inside each state
  - Expert systems
  - Neural network
  - Fuzzy logic
- Easily reconfigurable



Code Sample—State Template

```
public class StateDemo extends NormalState {
    public void setupDevices() {
      // Setup sensors/actuators the state interacts with
    }

    public void init() {
      // Called whenever the mission enters this state
    }

    public String process() {
      // Called by the control loop where the state can
      // process sensor data and act upon it
    }

    public void exit() {
      // Called upon exit of this state
    }
}
```

Code Sample—HeadPinger State

Head toward the Acoustic Pinger and surface while over it

```
public String process() {
    Point2D p = hydro.getPingerPosition();
    elevFilter.addValue(p.getY());

    if (p.getY() <= maxElevationForGoodHeading){
        heading.setTarget(hydro.getValue());
    } else {

        if (elevFilter.isFilled() && elevFilter >= elevationForSurface) {

            if ((currentTime - startOfState) > minTimeMs) {
                MissionLog.getInstance().log("Let's surface!");
                speedMeter.setTarget(0.0);
                return NEXTSTATE_ON_SUCCESS;  // Trigger for surface!
            }

        }
        MissionLog.getInstance().log("Elev. high, but delay not over");

    }
}
```

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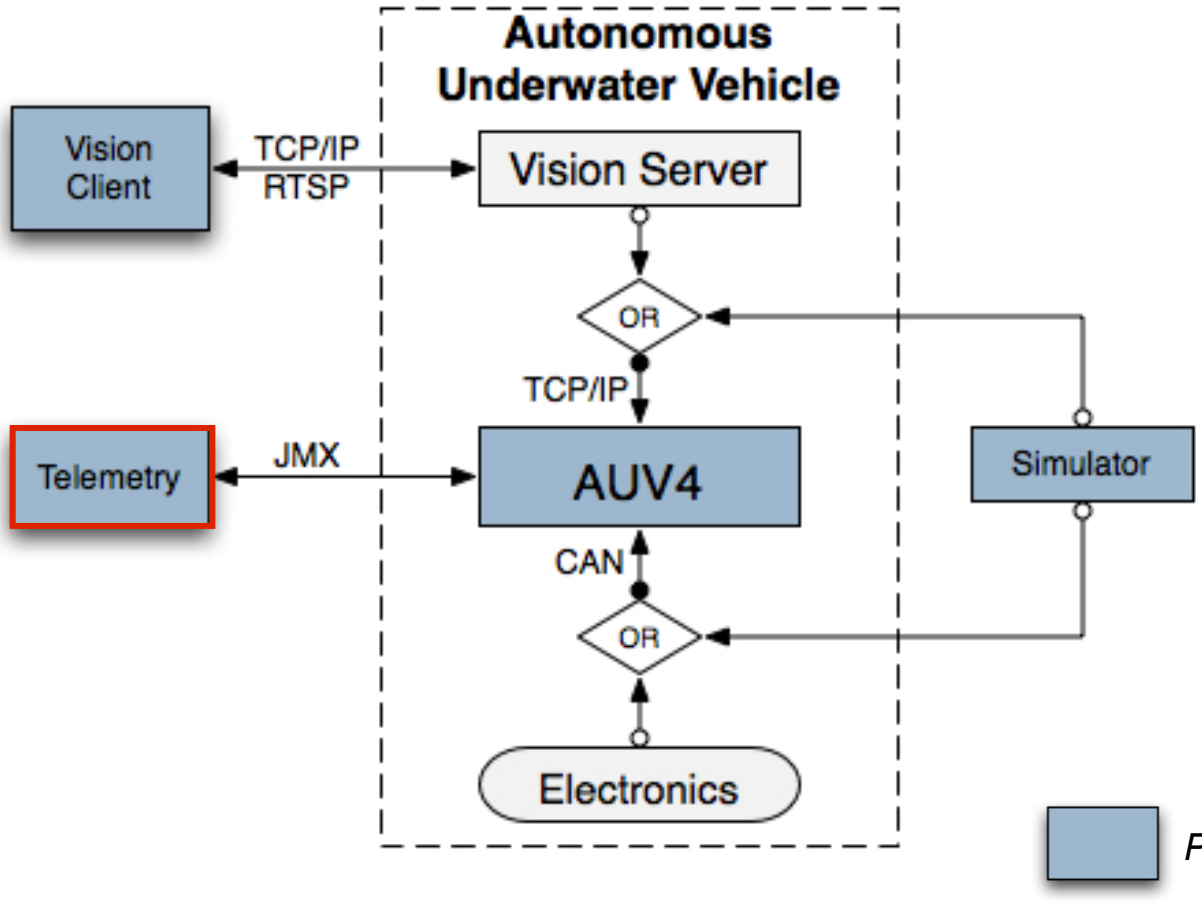


Telemetry

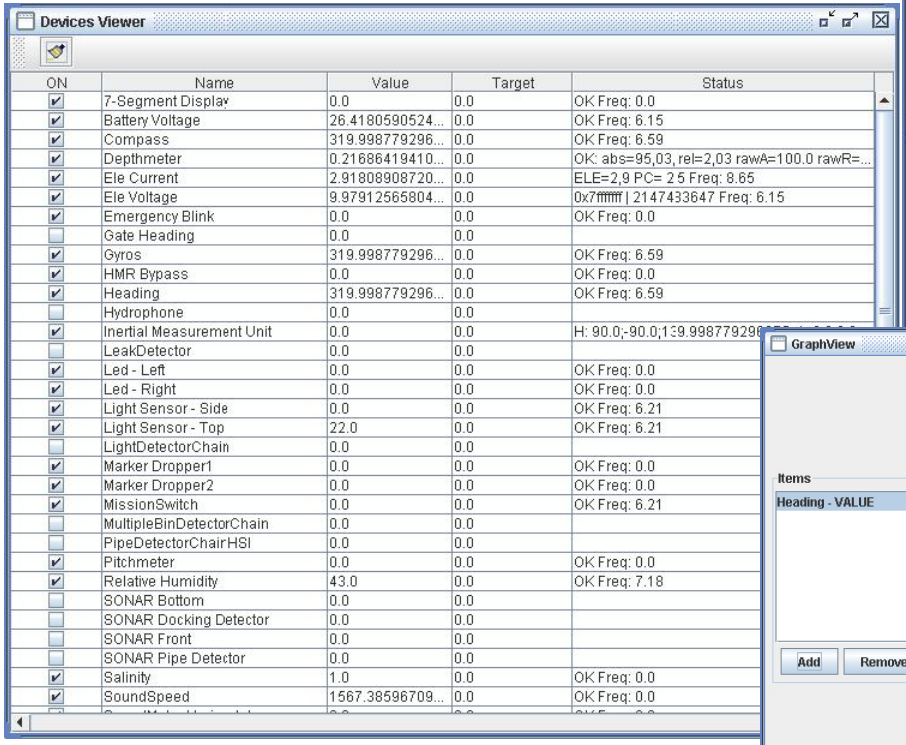
Remote measurement and management

- Enables
  - Remote configuration
  - Remote monitoring
    - Sensors
    - Actuators
  - Remote control
  - Data logging info
- APIs
  - Swing
  - Java Management Extension (JMX™)
  - JGraph

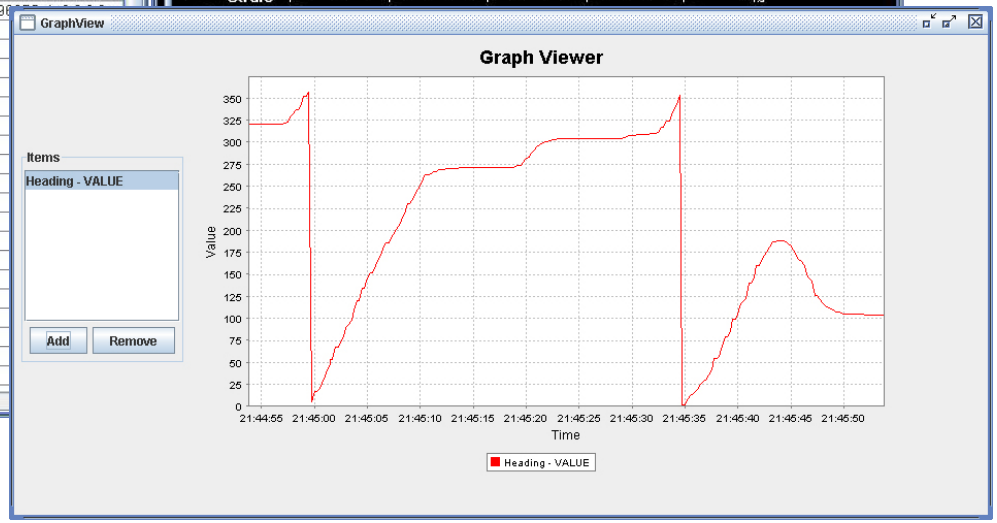
Telemetry

Remote measurement

Provides Navigation Information



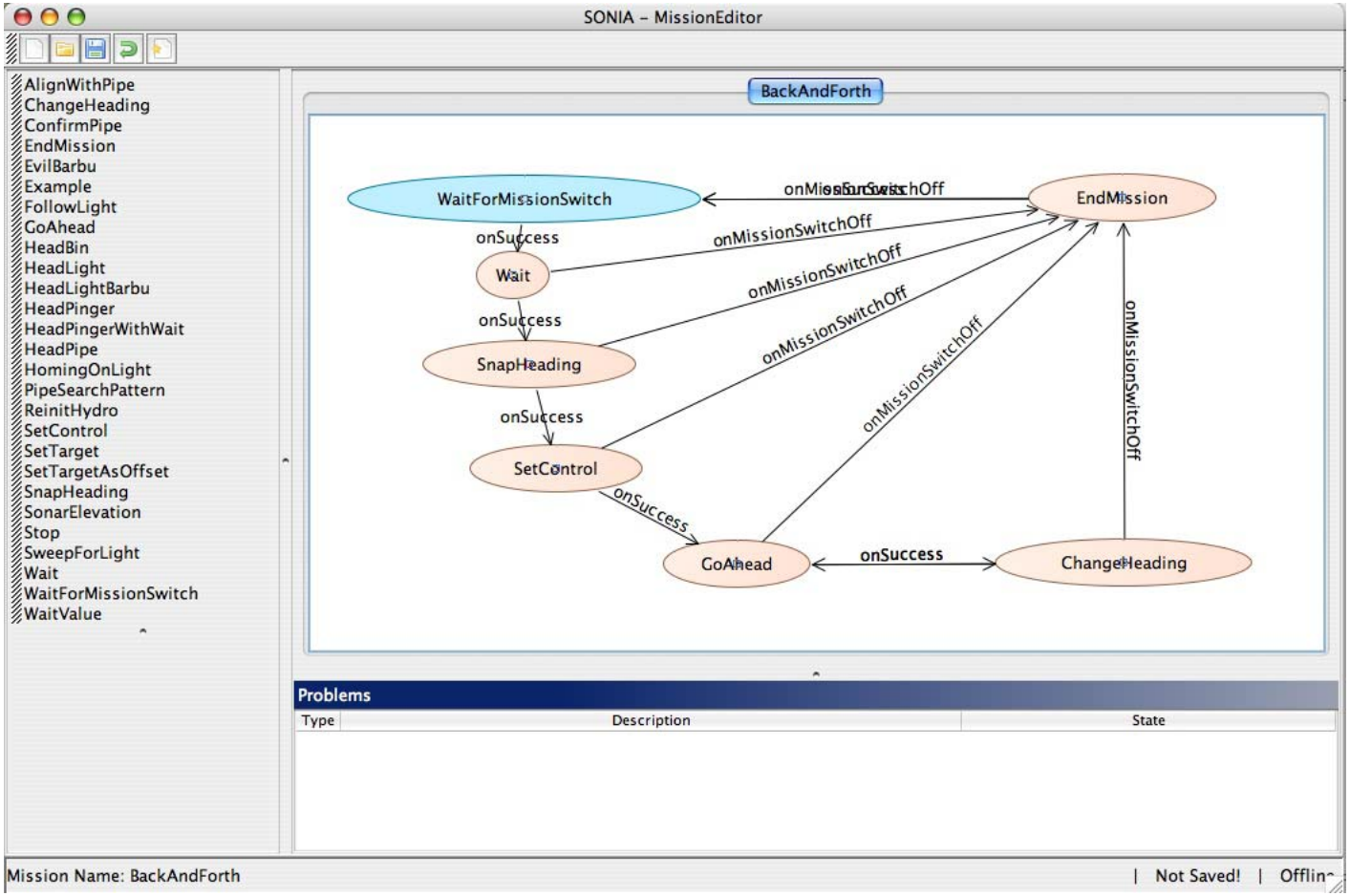
Display Sensors/Actuator Values



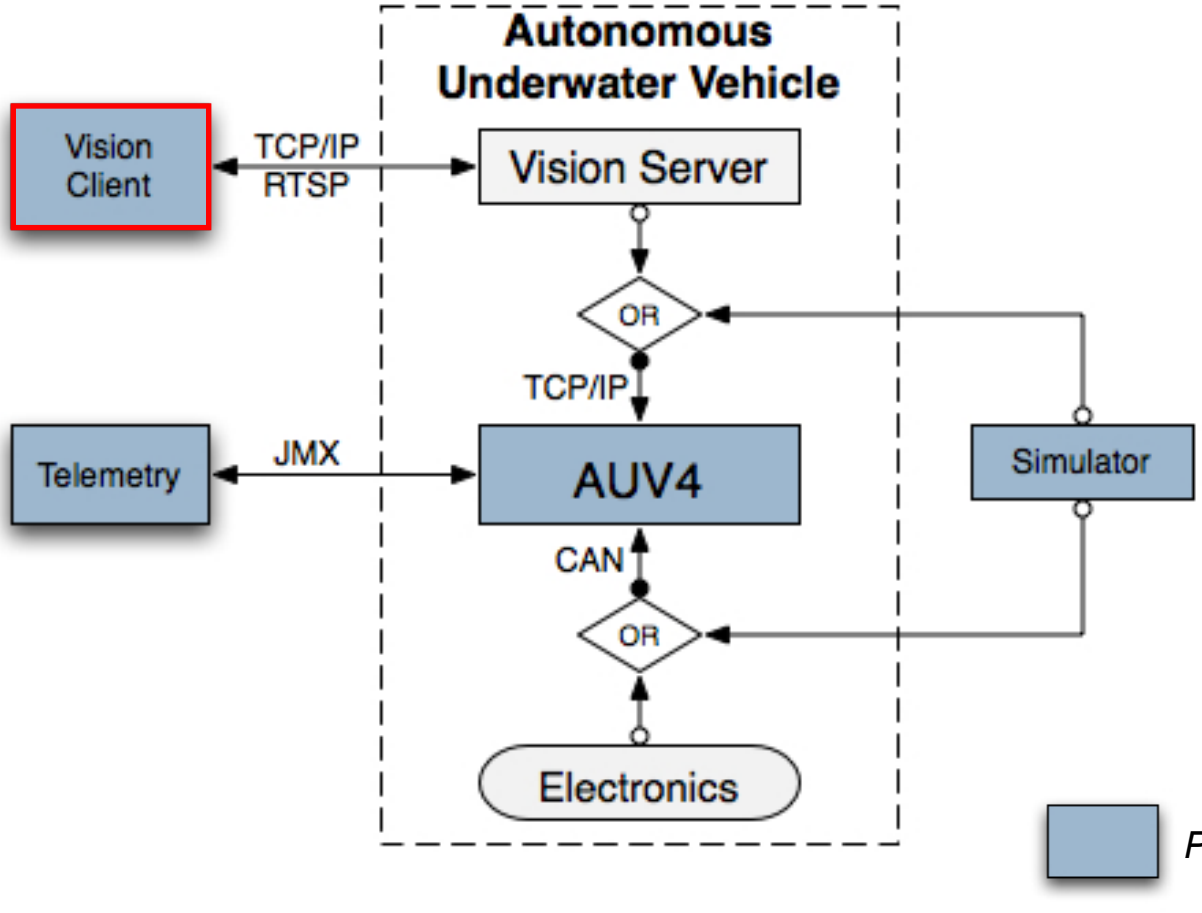
Graphical Display of Value Evolution vs. Time

Telemetry

Mission editor



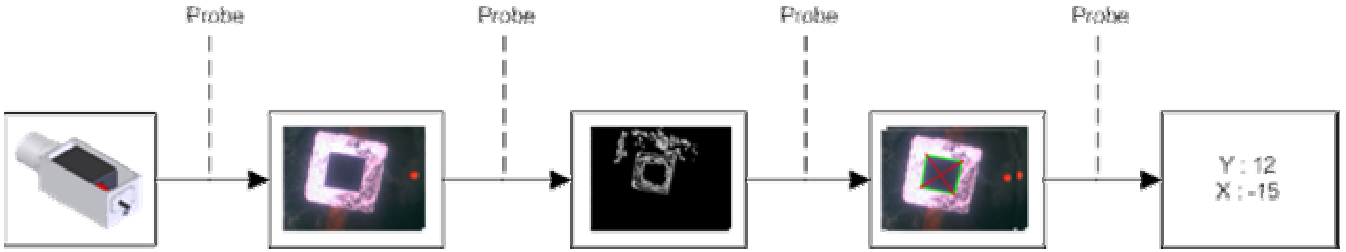
Software Architecture



Vision Client

Remote management

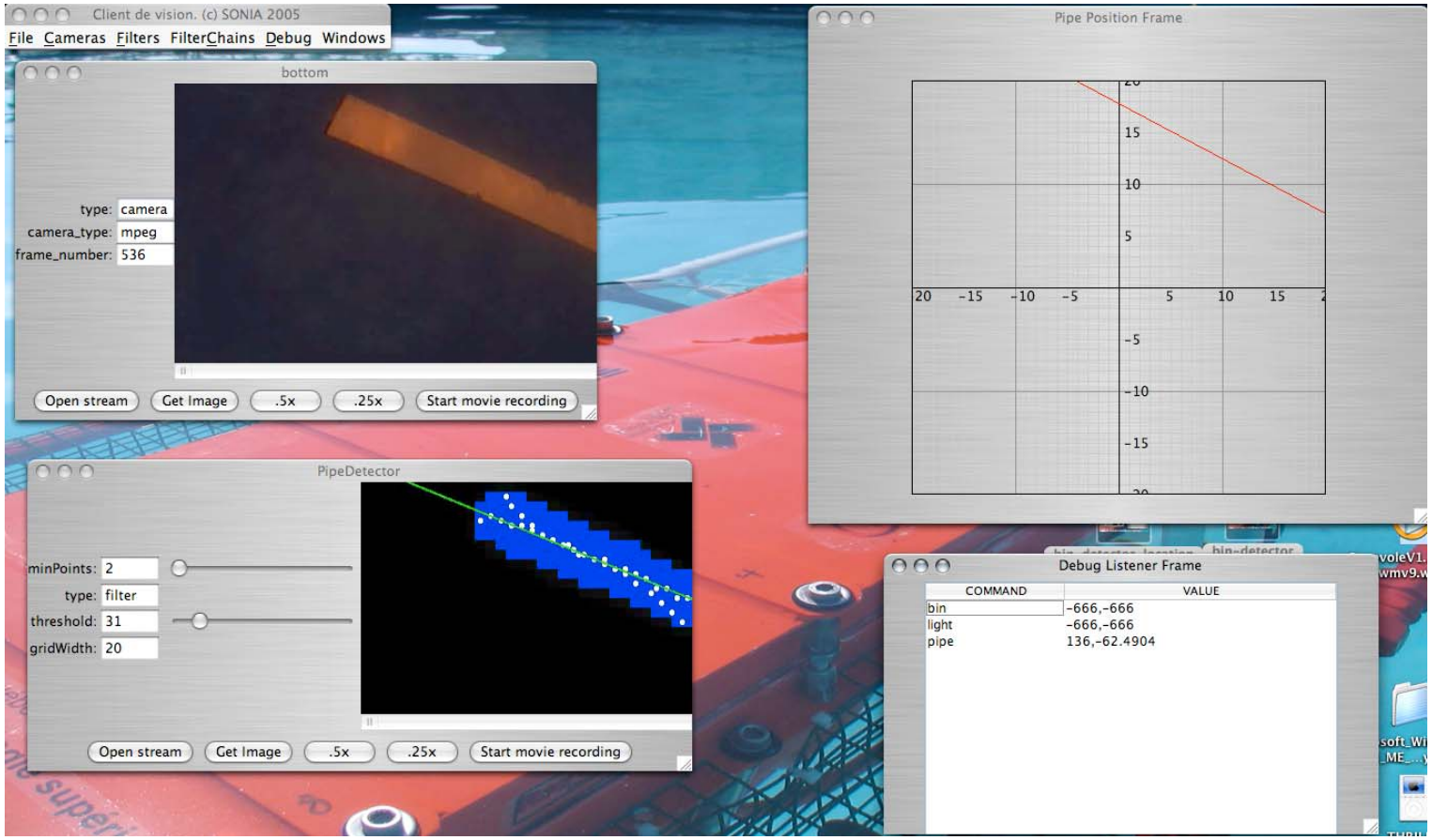
- Enables
  - Remote configuration of vision system
  - Remote monitoring of vision algorithm outputs
  - Customization of vision algorithms



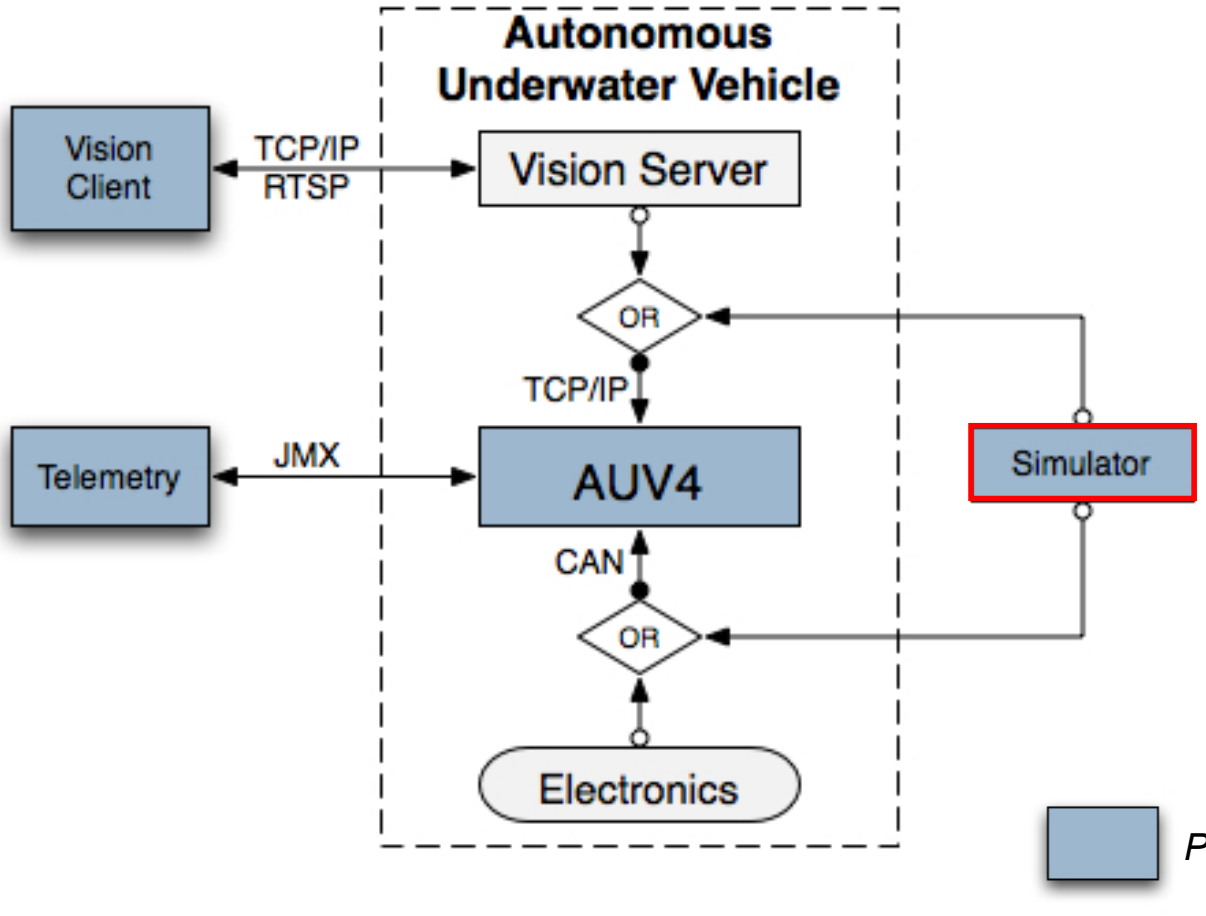
- APIs
  - Swing
  - QuickTime for Java technology (QTJava)

Vision Client

Remote management



Software Architecture

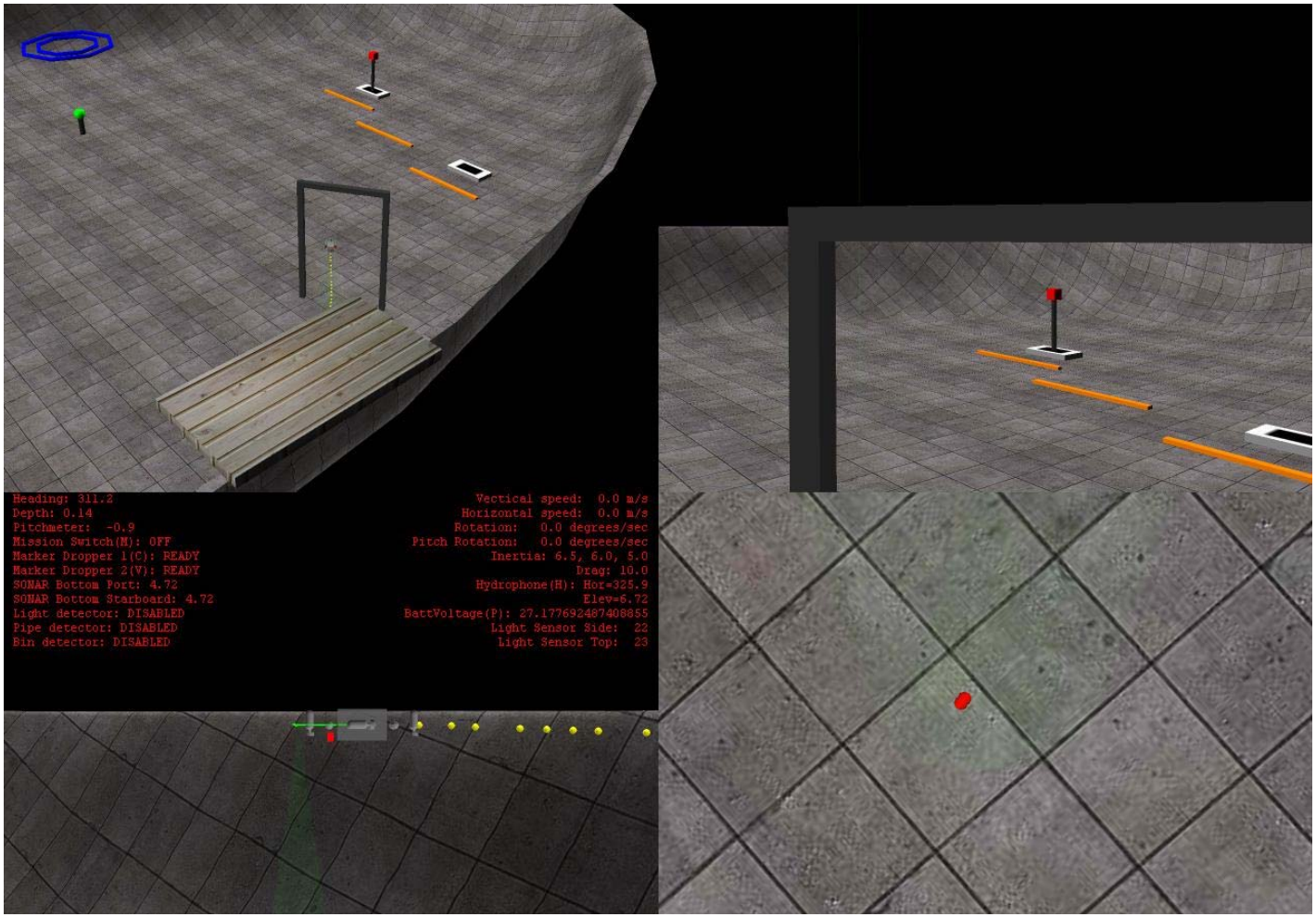


Simulator

Underwater 3D Simulator

- Simulates
  - Physical properties of the vehicle
  - Electronic interface
  - Simulates competition environment
  - Custom physic engine and model
- Easily test control and AI
- APIs
  - Java 3D™ API

Simulator


Heading: 311.2
Depth: 0.14
Pitchmeter: -0.9
Mission Switch(M): OFF
Marker Dropper 1(C): READY
Marker Dropper 2(V): READY
SONAR Bottom Port: 4.72
SONAR Bottom Starboard: 4.72
Light detector: DISABLED
Pipe detector: DISABLED
Bin detector: DISABLED
Vectical speed: 0.0 m/s
Horizontal speed: 0.0 m/s
Rotation: 0.0 degrees/sec
Pitch Rotation: 0.0 degrees/sec
Inertia: 6.5, 6.0, 5.0
Drag: 10.0
Hydrophone(H): Hor=325.9
Elev=6.72
BattVoltage(P): 27.177692487408855
Light Sensor Side: 22
Light Sensor Top: 23

DEMO

Tools

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Team Work

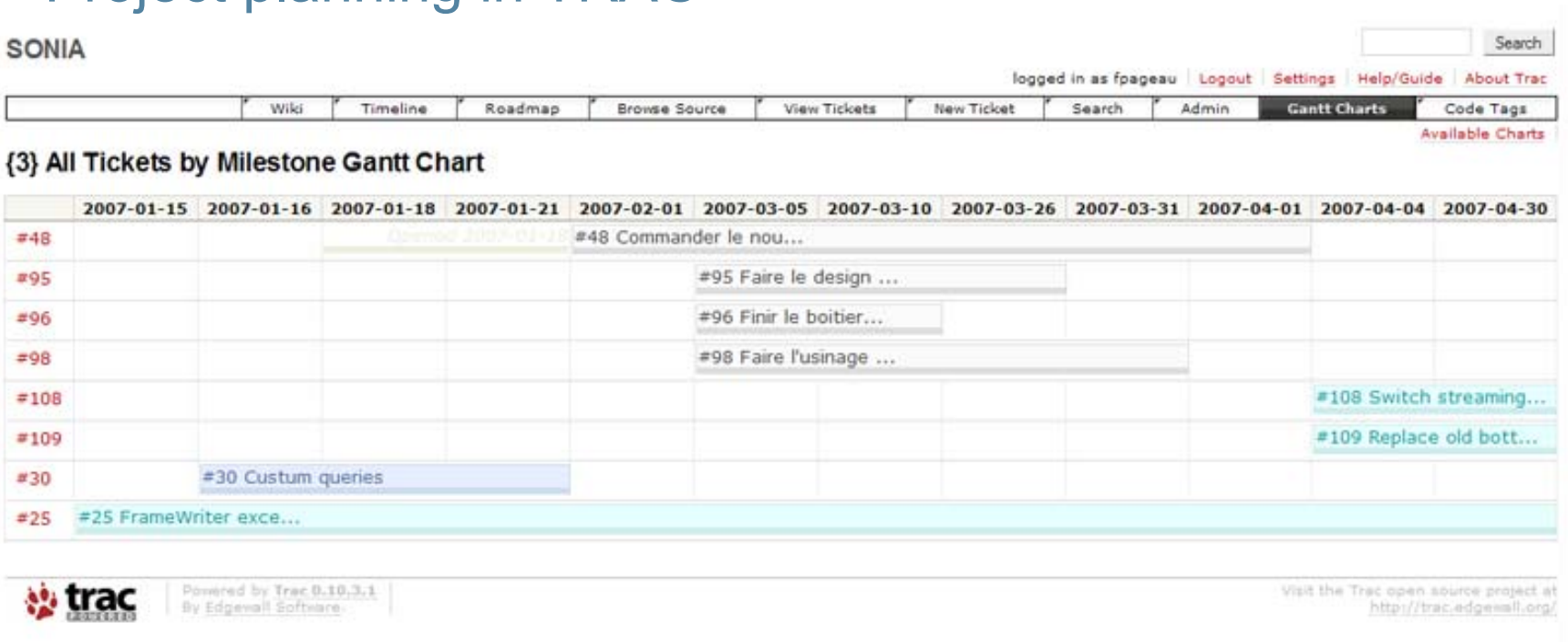
- Volunteer students
- Satellite members
- Unpredictable productivity
- Remote development (West-East-Europe)
- Different knowledge and backgrounds
- Multidisciplinary team
- Money is not a motivation

Methodologies

- Open source development tools
- Versioning system: SVN
- Project management and bug tracking: TRAC
- Content management: Wiki
- Code review: Diff email + RSS feed
- Pair programming
- Nightly build: Sending annoying emails on failure
- Standardized coding methodology and tools

Methodologies

Project planning in TRAC



Note:

- Timeline, roadmap, tickets (bug tracking) available online to all developers
- Allow remote management with team members in Boston, Menlo Park and Holland
- All modifications to tickets are subject to change notification (via RSS and email)

Methodologies

Change notification

Changeset 5236

Timestamp: 03/29/07 18:31:41 (2 weeks ago)
Author: fpageau
Message: Added the IMUHeading in the HeadingStatus? tx handler to be compliant with the 2007 Nav board

Files: trunk/SimSonia/src/simulator/net/protocoleCAN/handlers/tx/HeadingStatus.java (1 diff)

View differences: inline
Show 2 lines around each change
Ignore:
- Blank lines
- Case changes
- White space changes

Update

Unmodified | Added | Removed | Modified | Copied | Moved

trunk/SimSonia/src/simulator/net/protocoleCAN/handlers/tx/HeadingStatus.java

r4953	r5236	
67	67	`messageToSend.setData(4, previousHeading & 0xFF);`
68	68	
	69	`//IMU heading`
	70	`messageToSend.setData(7, (angle & 0xFF00) >> 8);`
	71	`messageToSend.setData(6, angle & 0xFF);`
	72	
69	73	`previousHeading = angle;`
70	74	

Note:

- Reviewed by all members of the field of study (Software, Electrical or Mechanical)
- Distributed as a RSS feed and ASCII based emails

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Competition Ranking

AUVSI final standings: From 2003 to 2006

	2003	2004	2005	2006
Cornell Univ.	1st	2nd	8th	7th
Duke Univ.	3rd	5th	4th	2nd
MIT	4th	1st	3rd	6th
SONIA AUV—ETS	**2nd**	**3rd**	**2nd**	**3rd**
U. of Florida	8th	7th	1st	1st
U. of Victoria	10th	10th	16th	14th

Source: AUVSI. *Final standings.* <http://www.auvsi.org/competitions/water.cfm>

Budget Comparison

AUVSI final standings: From 2003 to 2006

	2003	2004	2005	2006
Cornell Univ.	X	30,000	X	X
Duke Univ.	X	65,000	113,050	93,100
MIT	X	X	X	X
SONIA AUV—ETS	**22,000**	**30,000**	**44,000**	**62,000**
U. of Florida	X	X	X	X
U. of Victoria	13,000	X	X	160,000

Sources: Burdyny, Matt. U. of Victoria
http://robotics.pratt.duke.edu/archives/2005-2006/char_budget.html
http://robotics.pratt.duke.edu/archives/2004-2005/budget.htm
http://www.duke.edu/web/robotics/html/auv_budget.htm
http://www.engr.uvic.ca/~ess/modules/documents/files/endowment_2002A.pdf
http://www.news.cornell.edu/chronicle/02/8.15.02/Chronicle.pdf

Note : All budgets are in USD for ease of comparison.

Funding and Sponsorship

Past, present and future overview

SONIA AUV had a $70,000 CDN budget in 2006

- 74% of funding was from private donations
- 29 sponsors contributed to the project

SONIA AUV has a $60,000 CDN budget in 2007

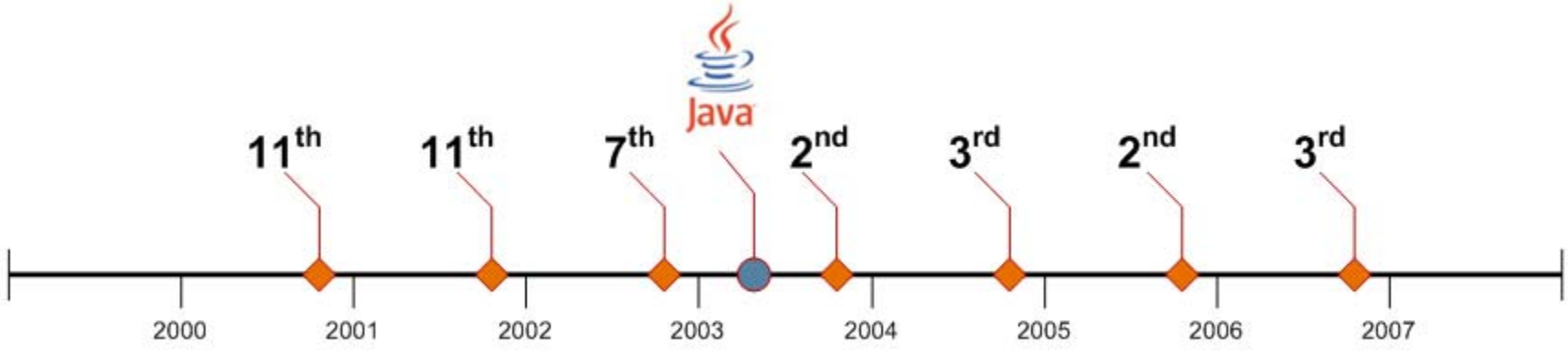
- 10% of the funding is still to secure
- 25 sponsors renewed their support

SONIA AUV needs to acquire new sensors for 2008–2009

- Doppler Velocity Log (DVL): positioning sensor worth $25,000
- Altimeters: 2x distance sensors worth $3000 each
- Your support is essential to our success

Summary

- Switch to Java technology for improved results
- Java technology is a prime choice for robotics
- Teamwork, creativity and innovation
- Low cost solutions
- Adapted methodologies



For More Information

List

- Sun Microsystems, 2006, *Meet SONIA*, <http://research.sun.com/spotlight/2006/2006-10-20_SONIA.html>
- SONIA AUV. 2006, *SONIA 2006: A Leap Forward*, <http://sonia.etsmtl.ca/doc/jpaper/jpaper_sonia_2006.pdf>
- AUVSI, 2007, 10th AUVSI & ONR AUV competition, <http://www.auvsi.org/competitions/water.cfm>

Glossary

Acronym	Definition
AI	Artificial Intelligence
API	Application Programming Interface
ASCII	American Standard Code for Information Interchange
AUV	Autonomous Underwater Vehicle
AUVSI	Association for Unmanned Systems International
CDN	Canadian currency
DVL	Doppler Velocity Log
ETS	École de Technologie Supérieure
IMU	Inertial Measurement Unit
ONR	Office of Naval Research
OO	Object Oriented
RSS	Really Simple Syndication
SONIA	Système d'Opération Nautique Intelligent et Autonome
SPAWAR	Space and Naval Warfare Systems Center
SVN	Subversion (http://subversion.tigris.org/)
TRAC	Open source, minimalist, web-based project management and bug-tracking tool. (http://trac.edgewall.org/)
USD	United States currency

Q&A

Félix Pageau

Martin Morissette

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