The Future of Ocean Innovation

ME Senior Design Class

Guest Lecture

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Mechanical Engineer

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Introduction

- Kevin Shimotsu
- Grew up in Kailua, HI
- B.S. (2007) and M.S. (2008) in Mechanical Engineering
  - University of Michigan – Ann Arbor
- Boeing Space & Intelligence Systems in Los Angeles (2009 – 2014)
  - Product Design in mechanisms, pyros, and electronics packaging for satellites
- Makai Ocean Engineering in Waimanalo (2014 – Present)
  - Project Management and Product Design in Makai Subsea Technology Group
Who is Makai?

Award-Winning Ocean Technology Co. ● Est 1973 ● 34 employees

Ocean Energy
- Pioneers of SWAC/OTEC
- World’s largest OTEC plant

Subsea Cable Software
- World’s #1 cable software
- Installed +250,000 miles

DoD S&T, Ocean Engineering
- Navy AUVs & platforms
- Subsea comms & sensors

ISO9001:2008 Certified

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Where is Makai?
Where is Makai?

We’re hiring interns… here!
OTEC Video...
Ocean Energy Research Center

World’s largest operational OTEC plant • **Navy funded** • Kailua-Kona, Hawaii

- Heat Exchangers
- Marine Pipelines
- Turbine-Generators
- Corrosion
- OTEC Plant Designs
Marine Corrosion Laboratory

Sophisticated lab & equipment, Ph.D. scientists & engineers

Automated tools for remotely controlled experiments

Used by multiple OTEC developers to test materials & HEXs in real deep seawater 600m and 915m depths.

<table>
<thead>
<tr>
<th>Seawater</th>
<th>Warm</th>
<th>Cold</th>
<th>Deep/Cold</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intake Depth</td>
<td>20 m</td>
<td>670 m</td>
<td>915 m</td>
</tr>
<tr>
<td>Temp</td>
<td>23 deg C</td>
<td>5 deg C</td>
<td>4 deg C</td>
</tr>
</tbody>
</table>
## Makai’s Pipes at NELHA

<table>
<thead>
<tr>
<th>Installed Date</th>
<th>Diameter [meter]</th>
<th>SW Flow [liter/min]</th>
<th>Depth [meter]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980</td>
<td>0.3</td>
<td>4,600</td>
<td>150</td>
</tr>
<tr>
<td>1987</td>
<td>0.46</td>
<td>11,000</td>
<td>640</td>
</tr>
<tr>
<td>1987</td>
<td>1.0</td>
<td>51,000</td>
<td>670</td>
</tr>
<tr>
<td>2001</td>
<td>1.4</td>
<td>100,000</td>
<td>915</td>
</tr>
</tbody>
</table>
Launch Recovery Transport Vehicle

Reliable, low-cost transport & launch for submersibles in rough seas.

- **Launch**: Stable surfacing and submergence
- **Recovery**: Minimal relative motions between payload and platform
- **Transport**: Aluminum barge surface tow and transport

LRT-30

LRT-80: Payload of 80k lbs. (dry)
Cable Modeling - *MakaiLay™*

- World’s #1 cable laying software
- Used by 80% of global cable ship fleet
- Installed over 250,000 miles of cable
- Over $35M in revenues = robust
- 3D, dynamic, rigorous physics

**Commercial Cables**

- Telecom
- Power
- Oil & Gas

**Defense**

- Towed
- Fixed
- Cable Networks
Practical Lessons from the Design, Build, and Testing of a Novel Autonomous Underwater Vehicle

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Overview

• Makai’s Autonomous Underwater Vehicle (AUV) project.
• Engineering design process discussion.
  • Requirements Definition
  • Conceptual Design
  • Preliminary Design
  • Detailed Design
  • Manufacturing & Testing
AUV Project Background

• Makai has designed, built, and tested a bottom-skimming AUV which can be used to install oceanographic sensors in the seabed for environmental monitoring.
• Start: 2011
• Successful demo: 2015
• Homing and docking capability recently added.
VIDEO...
Requirements Definition

1. How the customer explained it
2. How the project leader understood it
3. How the engineer designed it
4. How the programmer wrote it
5. How the sales executive described it
6. How the project was documented
7. What operations installed
8. How the customer was billed
9. How the helpdesk supported it
10. What the customer really needed
Requirements Definition

- **LISTEN** & seek to understand client.
- If they are unsure, tell them what you think they want & confirm.
- Iterate on requirements early & often:
  - They may want a tire swing made out of unobtainium
  - Perform ROM estimates to avoid sticker shock
- **DOCUMENT** & share w/ client
- **Confirm, Confirm, Confirm.**
Requirements Definition: Contract / Engineering

• Types of requirements
  • Contractual requirements: Budget, schedule, deliverables
  • Engineering requirements: Size, weight, power, etc.

• Requirements determine how you will be graded, so negotiate hard!
  • If you want an A+, make it easy to get one.
  • Over-defining requirements is possible.
Design Phases

• Conceptual Design
  • The physics and economics makes sense.
  • Passes the “laugh” test.

• Preliminary Design
  • Critical components selected and design takes on a realistic form.
  • Perform tests early to reduce risk.

• Detailed (Final) Design
  • Every single facet defined.
  • Ready to transition to a real attempt at the deliverable product.
Design Phases

Conceptual Design 2011

Preliminary Design 2012

V1 Detailed Design 2014

V2 Detailed Design 2015
Conceptual Design

• Find out what your client wants!
  • Makai’s client wanted Cheap & Fast
• Cost-conscious mentality drove a lightweight, low power, and simple design.
• Fast development led to a few issues along the way, but ultimately on-time delivery.
• Your client’s priorities will shape your design.
Conceptual Design

• Most of the conceptual design actually happens before proposal submission.

• Make rough order of magnitude (ROM) calculations.
  • Verify physics – Focus on size, weight, and power.
  • Assess dependent technology.
  • Estimate cost and schedule.

• Simple calculations will eliminate ~90% of your concepts.

• MARKET RESEARCH!
Preliminary Design

- Add realism to your conceptual design.
  - Define subsystems and interconnections (block diagram).
  - Select sensors, actuators, power/control electronics, etc.
  - Revise simulations and analysis.
- Research the state of the art.
  - Save time and money by using existing know-how & technology.
  - Only invent things that matter!
Preliminary Design

• **Reduce risk early** with concept validation tests.
  • Hardware testing will identify the 50 problems you couldn’t simulate.
  • Independently test subsystems to simplify troubleshooting.
  • Money spent on early testing WILL save you time and money in the future.
Detailed Design

• Finalize design details in all aspects of the system
  • Modeling: Fasteners, cables, piping, tubing
  • Analysis: Final structural, thermal, flow, mechanical stability, power/energy, vibration/shock
  • Material selection: Corrosion, thermal expansion, moisture absorption, UV/chemical sensitivity, lubrication, etc.

• EVERYTHING in your design should have a FULL part number.
  • A part with a full P/N can be ordered by ANYONE.
  • Old designs can be revived without “tribal knowledge”.
**Detailed Design**

- Design structure organization is critical!
- Break into manageable subassemblies.
- Maintain entire design in a single location (with backups).
- Track it in a bill of materials.
Detailed Design

- NAG your vendors to stay on schedule!
  - Most vendors HATE prototypes.
  - Send a spec or drawing for custom complex designs.
  - Machine shops generally have bad schedule management and customer service.
- Shipping speed and packaging.
  - Shipping to Hawaii is EXPENSIVE!
  - Assume UPS will punt your box into the truck.
Detailed Design

- Design for Manufacturability and Test (DFMAT)
  - Don’t make assembly impossible!
  - Assume you will reassemble a prototype at least 5 times.
  - How will you lift it?
  - How will you maintain it?
Detailed Design

- Engineering drawings are a **contract**.
  - Defines a **finished** product, not how to make it.
  - Drawings should stand on their own.
  - Proper GD&T minimizes clutter and confusion.
- Tip: Conservative machinists typically cut to **MMC**.
Manufacturing

• Engineers are NOT machinists (Does not apply to FREE engineering student labor)
  • $70K salary ($34/hr) + overhead = $100-$175/hr charged to your client.
  • Machine parts yourself only in emergencies.

  *Vendors make mistakes!

• Buy spares! Why buy 1 part when you can get 2 for twice the price?
• Rule of thumb: Assume your build will take 3x longer than your most optimistic estimate.
Testing

- **Always start with a plan**... and be ready to change it.
- Get familiar with your test facility.
  - Water depth, humidity, utilities, nearby hardware stores, civilian traffic, etc.
- **Failure** is a learning experience!
  - Identify the cause, correct it, document it, and move on.
  - If you caused the failure, **OWN IT**! People will respect you for this.
  - Corrective actions make your design more robust.

Battery destroyed by impact due to undersized shackle

Cracked welds

Added reinforcement
Closing Remarks

- You are an engineer, not a scientist!
- Always have a plan, but be ready to change that plan!
- Failures suck, but ultimately make you stronger.
- Luck counts! Luck is when opportunity meets preparation.
MAHALO!

Questions?

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