AC 2008-1426: NEED DEFINITION FOR INTERNATIONAL HUMANITARIAN DESIGN PROJECTS: A CONTEXTUAL NEEDS ASSESSMENT CASE STUDY FOR REMOTE POWER

Ryan Norton, LeTourneau University

Matthew Green, LeTourneau University

Paul R. Leiffer, LeTourneau University

PAUL R. LEIFFER, PhD,PE Paul R. Leiffer is a professor in the School of Engineering and Engineering Technology at LeTourneau University, where he has taught since 1979. He is currently co-developer of the program in BioMedical Engineering. He received his B.S.E.E. from the State University of New York at Buffalo and his M.S. and Ph.D. degrees from Drexel University. Prior to joining the faculty at LeTourneau, he was involved in cardiac cell research at the University of Kansas Medical Center. His professional interests include bioinstrumentation, digital signal processing, and engineering ethics. Email: paulleiffer@letu.edu.

Need Definition for International Humanitarian Design Projects: a Contextual Needs Assessment Case Study for Remote Power

Abstract

A student team designed, prototyped, and tested a system with the end goal of providing 2.5kW-hr/day of electrical power in remote areas, captured from a river with no dams or significant potential energy change. The project was sponsored by two international service organizations with need for remote power. The design team applied a recently published design method specifically developed for frontier design projects, that is, projects beyond the experience and expertise of the designers. The team applied the "Contextual Needs Assessment" method to identify important contextual influences and guide customer interviews. The resulting contextual data proved profoundly important to correct need definition and design direction for the project. Contextual interview transcripts provided the basis to form a customer needs list and design specifications. This paper describes the project partners and goals, contextual needs assessment method, project results, and specific design decisions impacted.

1 Introduction and Background

Many engineering schools are now employing a service-learning approach to globally-based humanitarian projects[1,2,3,4]. The importance of integrating both globalization and social needs into the engineering curriculum is acknowledged by the ABET criteria[5], and human need is a clear priority of the engineering profession, as indicated in the NSPE creed[*,6]. However, the majority of North American engineering students are not familiar with the contexts in which vast needs exist, such as those among the physically disabled or the estimated 4 billion people living on less than $2 a day (PPP)[7]. These conditions represent a formidable "frontier design environment", or environments outside the experience and expertise of most engineering students.

Sufficiently understanding design needs is notoriously problematic in frontier environments where data and contextual experiences are not readily available. This is a challenge faced by organizations such as Engineers for a Sustainable World, Engineers without Borders, and other Non-Government Organizations engineering high human-impact solutions in these unfamiliar contexts. In response to this need, a basic but powerful "Contextual Needs Assessment" method has been recently published which improves discovery and application of contextual information vital to successful frontier design[8,9]. By improving contextual needs assessment, the method increases the successful application of engineering to such high human-need environments as poor areas of developing countries and persons with disabilities.

Two international service organizations recently requested a student team to design, prototype, and test a system to provide 2.5kW-hr/day of electrical power in remote areas, from a river with no dams or other significant elevation change. The design team applied the Contextual Needs Assessment method to identify important contextual influences and guide customer interviews. Contextual interview transcripts provided the basis to form a customer needs list and design specifications. The resulting contextual data proved profoundly important to need definition and design direction for the project. This paper describes the project partners and goals, contextual needs assessment method, project results, and specific design decisions impacted.

1.1 Design Need: Remote Electricity

From a global perspective, many remote areas have either unreliable electrical power or no power at all[10]. Two organizations, I-TEC and HCJB, need reliable power sources in remote locations. These organizations are currently hindered from radio broadcasting and medical services in certain areas in order to pursue their organizational missions. Creating a remote power module will empower both companies to fulfill their missions in several capacities in remote areas. Both organizations have expressed a specific interest in producing electrical energy from a flowing stream with minimal site works (e.g. no dams).

1.2 Why Micro-Hydro?

Two of the leading technologies for frontier power generation are fossil-fuel based generators and solar photovoltaic (PV) cells. These technologies are useful, but both have limitations that can affect their usefulness. Portable gasoline powered generators are useful because they can operate in almost any environment, can operate at any time or duration of time, are transportable,

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[*] "As a Professional Engineer, I dedicate my professional knowledge and skill to the advancement and betterment of human welfare …" (NSPE Code of Ethics for Engineers).

reasonably priced, and can have a large power output. The main disadvantages for such generators are the reliance on fossil fuel, noise, and maintenance. The reliance on fuel for operation prohibits the generators from running continuously without operator intervention, adds a recurring cost, and relies on fuel availability. Likewise, the generator needs to be maintained regularly to ensure a long work-life.

Photovoltaic (PV) power generation is becoming more common due to ease of use and lower maintenance requirements. The advantage of photovoltaic generation is that once the cells and battery system have been installed, little or no maintenance is required over years of usage. The disadvantages of photovoltaic generation stem from the reliance on sunlight and the life expectancy of the battery storage system. Sunlight is not always plentiful in the location and time most desirable for power generation.

As a result of the disadvantages of other technologies, micro-hydropower generation from flowing water is of great interest to I-TEC and HCJB due to their work in remote locations. The advantage of micro-hydro requiring no civil works is that it could be brought to a remote location and be easily installed. Once installed, it would be able to generate power constantly and require little or no maintenance. The disadvantages of a micro-hydro solution would be a possibly higher initial expense and long-term maintenance such as battery replacement. Thus, the micro-hydro solution would be able to offer both the power availability of a gas generator and the low operator intervention and recurring costs of photovoltaic power generation with the least amount of disadvantages.

1.3 Interdisciplinary Senior Design at LeTourneau University

Student involvement in interdisciplinary teams is not only an expectation of industry but also has become a required outcome of the ABET engineering criteria[11]. Our university offers a Bachelor of Science degree in engineering (general engineering) with concentrations in biomedical (BME), computer (CE), electrical (EE), mechanical (ME), and materials joining engineering (MJE). Much of the curriculum is interdisciplinary. Design projects have been included in several of these courses. In parallel, the Department of Engineering Technology offers a bachelor of science degree in engineering technology, with concentrations in electrical (EET), mechanical (MET), and materials joining engineering technology (MJET).

An emphasis on design projects is a historical strength in the LeTourneau University school of engineering, and has been developed especially well in the last 10 to 15 years as senior design projects have become more ambitious and have also expanded to include significant applied research projects. In addition, underclass courses have also embraced the project experience to a large degree. We view this project orientation as a significant strength, defining our programs and providing a distinct educational advantage for LeTourneau students.

Senior design initially consisted of one-semester individual projects. These were changed to team projects in 1992 and, at the recommendation of an ABET visiting team, to two-semester team projects in 1997/98 school year.

Our first fully interdisciplinary projects were begun in 2001/02 as electrical and mechanical students worked together on an EMG-driven artificial arm prosthetic project, and electrical and mechanical students worked on an SAE Formula racecar. (Mechanical students designed the chassis and mechanical systems, while electrical students developed the instrumentation and dashboard displays). In 2001/02 a team of electrical, mechanical, and computer engineering students, along with computer science students, developed a walking robot for the SAE competition, taking first place at the national competition.

During the period from 2001 to 2006, three separate course tracks were offered – EE Design (including CE students) I and II, ME Design I and II (including BME students), and MJE* Design I and II. The major interdisciplinary projects during this period are itemized in Table 1.

Table 1: Major Interdisciplinary Projects From 2000/01-2006/07

1. **The Phoenix Project (EE, ME, CE)** – autonomous navigation and flight by a radio-controlled helicopter
2. **Artificial Arm (BME, ME, EE, CE)** – a powered prosthetic with artificial muscles controlled by EMG signals
3. **Formula SAE (ME, EE)** – Formula-style racecar for the annual SAE competition
4. **Walking Robot (EE, ME, CE, CS)** – an SAE competition walking robot to autonomously seek a light beacon while navigating an obstacle course
5. **ACL (BME, ME)** - quantify the effect of ACL injury in the human knee using a programmable test mechanism and an electronic controller designed by the team.
6. **AISC (MJE, EE)** - increase the quality and reliability of drawn-arc stud welds made through galvanized decking onto coated steels.
7. **AMI – Accessible Medical Instrumentation (EE, CE, BME)** - design and build an affordable vital signs monitor that is appropriate for home use and is accessible for persons with vision, hearing, or motor skills impairment.
8. **Coil Design (MJE, EE)** - efficiently produce coil-end butt welds on advanced high strength metals.
9. **I-TEC Powered Parachute (ME, MT)** - design and fabricate a durable aerodynamic mast system to shorten takeoff distances for powered parachute flights, specifically for use by indigenous peoples served by Indigenous People's Technology and Education Center.
10. **L.E.G.S. - LeTourneau Engineering for Global Solutions (BME, ME)** - design and test a culturally appropriate, durable and affordable lower limb prosthesis for use in developing nations.
11. **LIRA - LeTourneau Robotic Arm (EE, ME, CE)** - design a new electrical joint capable of infinite rotation and incorporate this joint into a full-scale industrial robot.
12. **SAE Aero Design (ME, MT)** - design and build a high-lift radio-controlled airplane to compete in the SAE Aero Design competition.
13. **SAE Formula Car (ME, EE, MT)** - design and build a formula style racecar to compete in the SAE Formula competition.
14. **SAE Mini-Baja (ME, MT)** - design, build, and test two off-road Baja vehicles to compete in the SAE Mini Baja competitions.

* Formerly known as Welding Engineering (WE)

All senior engineering students began meeting together once a week for most of the spring semester in 2003 in a seminar format to discuss issues of engineering ethics, standards, and professionalism.

It became apparent that students were not uniformly prepared for senior design, so in response a major curriculum enhancement was implemented in 2006-2007 to build upon the existing project-emphasis strength and further improve engineering design projects. The changes required no new faculty resources and did not change the credit hour requirements of any degree plans. As new interdisciplinary design teams were created and non-interdisciplinary teams continued, several problems arose dealing with consistency of faculty involvement and grading. For these reasons, a common interdisciplinary senior design experience was implemented in 2006-2007 for all students, in both engineering and engineering technology. The curriculum changes promise a higher quality senior design experience through improved student preparation throughout the curriculum, increased faculty supervision in senior design, and fully interdisciplinary projects.

2 Design Project Team, Partners, and Goals

HCJB Global requested our university conduct a student design project in support of their Micro-power project. I-TEC quickly agreed to co-sponsor the project by serving as a customer, since the design work is in line with their mission. Five senior and three junior design students indicated the project as their first choice, and SPARC was born (Figure 1 and Figure 2.)

Figure 1: SPARC Logo (Supplying Power Alternatives for Remote Communities)

Figure 2: The SPARC Senior Design Team*
(Left to right: Micah Cary, Gordon Strodel, Ryan Norton, KJ James, David Brown, David Wilcox, Jonathan Nelson, Scott Grove, Brandon Johnson, Dr. Matthew Green)

2.2 I-TEC (Indigenous peoples Technology and Education Center)

The Indigenous Peoples Technology and Education Center (I-TEC)[12] works to empower indigenous peoples through technology and education. I-TEC was founded by Steve Saint[13], son of legendary martyr Nate Saint[14], to assist indigenous peoples like the Waodani Indians Steve grew up with. I-TEC's past projects include visual training modules, backpack dental chairs, and powered-parachutes for transportation in frontier areas. Some of the projects I-TEC has developed are a thirty-five pound dental chair and drill and the Maverick, a prototype off-road/aerial vehicle that can carry four passengers. I-TEC desires to use electricity in remote areas for medical equipment, office equipment, and maintenance.

2.3 HCJB Global

HCJB was the name of the first radio call name of what is now HCJB Global[15] in Quito, Ecuador. HCJB has two main areas of focus: HCJB Voice, their media ministry and HCJB Hands, their medical ministry. Today, HCJB healthcare ministries and radio broadcasts impact more than 100 countries. The Micro-power project currently underway at the HCJB Global Technology Center[16] in Elkhart, Indiana seeks remote power solutions in support of HCJB's mission. HCJB's mission is "To empower dynamic media and healthcare ministries that declare and demonstrate Jesus Christ," and their vision is "To see people everywhere transformed in Christ, engaged in the growing church, and empowered to ignite reproducing ministries that bring His light to their communities." HCJB desires to use micro-hydropower with for medical, broadcasting, and office needs.

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* Seniors: 4 Mechanical Engineering (ME) and 1 Mechanical Engineering Technology (MET); Juniors: 2 ME and 1 MET; Sophomores: 1 Electrical Engineering; Faculty: Mechanical

3 Understanding Frontier Needs – Applying the Contextual Needs Assessment Method

The SPARC design team faced the challenge of thoroughly understanding the needs and context which were both foreign to the team's experience and expertise as well as inaccessible and widely variable. Additionally, the team had no experience with or access to existing micro-hydro installations. The project scope and goal needed to be appropriately clarified through phone calls and research. This daunting task clarification phase was facilitated through the application of the contextual needs assessment method, which dramatically increased effectiveness while decreasing person-hours and frustration. The next section overviews the contextual needs assessment method as published, followed by section 3.2 describing how the team customized the method for the micro-hydro project. Section 3.3 provides results including samples of an interview transcript, customer needs, and specifications.

3.1 The Contextual Needs Assessment Method (as Published)

The Contextual Needs Assessment Method[17,18] summarized in Figure 3 improves task clarification through a new focus on context. The contextual focus is especially critical for needs which are "frontier" or foreign to the designer. Testing under both laboratory and normal classroom conditions shows the new method is extremely effective, easy to use, and well received by students[19].

The contextual needs assessment method incorporates traditional customer needs methods, but extends significantly beyond these by formally incorporating contextual information. Step (1) calls for identification of as many of the relevant contextual factors as feasible by utilizing any of the factor identification techniques provided (Figure 3). Context factors refer to items such as where, how, and by whom the designed system will be used. Templates are the most basic and powerful technique provided for context factor identification, and a recent version* is given in Appendix A. Step (2) of the method involves translating each factor identified in Step one into the form of one or more questions. Step (3.1) may be fulfilled with established needs elicitation techniques such as like/dislike or articulated use. Step (3.2) involves answering the questions generated in Step two through customer interviews or research. Step (4) refers to standard needs aggregation techniques such as affinity analysis. Step (5) involves identifying the different factor values to be addressed by one or more products, noting any additional customer needs identified.

1. Identify relevant contextual factors
2. Generate list of contextual questions to be answered (modify provided template)
3. Gather customer needs and factor values
   - 3.1. Gather customer needs
   - 3.2. Gather factor values
4. Aggregate customer needs into weighted list
5. Aggregate factor values into context scenario(s)

Figure 3: The Contextual Needs Assessment Method as Published[17,18]

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* Available electronically, email MatthewGreen@letu.edu.

The contextual needs assessment method facilitates and directs the process of discovering, documenting, and applying contextual information and is easily adaptable to a variety of design needs. The straightforward method provides valuable structure and insight for organizing and driving the needs assessment process, and the templates place the power of contextual assessment in the hands of even novice engineers who are tackling a design need outside of their experience and expertise. More details of the method are available in the publications referenced here.

3.2 Customizing Contextual Needs Assessment for the Micro-Power Project

No site visit or articulated-use customer interviews were possible. Thankfully, the two project customers are lead users with unusual insight into the design need context. This combination of an inaccessible context along with knowledgeable customers made the contextual needs assessment method even more instrumental to project success. The team customized the method and templates to fit the project.

3.2.1 Customizing the Contextual Needs Assessment Method

The Contextual Needs Assessment Method was customized as shown in Figure 4. In the customized version of the method, step (1) involved adding a few contextual factors to the template. Step (2) involved modifying the generic template questions to fit the project. Step (3) was completed by answering the questions generated in Step two primarily through customer phone interviews augmented with research. Step (4) involved inferring customer needs from the interview transcript (rather than an articulated use interview or a like/dislike method.) Step (5) involved translating the needs identified from the interview into quantifiable specifications.

1. Add additional contextual factors to template (brainstorming)
2. Modify and add contextual questions in template
3. Answer contextual questions (phone interviews)
4. Develop customer needs list from interview transcript
5. Develop specifications from interview transcript and customer needs

Figure 4: The Customized Contextual Needs Assessment Method

3.2.2 Customizing the Contextual Needs Assessment Templates

The contextual needs templates were modified to fit the project. Table 2 shows the modified questions in bold (with the generic question prompts in non-bold). The complete set of contextual questions is in Appendix A.

Table 2 Snapshot - Contextual Needs Assessment Template with Modified Questions

HOW: Usage Application		
#	Context Factor	KEY: Plain type: Template CNA Questions v3.0 ***Bold Italics: customized question for SPARC project***
a0	task application	What specific purpose(s) will product be used for? How will the product be used? ***What equipment/purpose(s) will need power?***
a2	task quality	What quality of the primary function is needed? ***What are the output power requirements? What voltage/current (w/tolerances) must the product provide? Will it need "bursts" of power?***
a6	task quantity	How much quantity of the product's output is needed? ***How much energy is needed for a day? What is the peak power need?*** ***Will several forms of power be needed simultaneously?***
a9	transportation type & amount	How often, how far, and in what way will product be transported? ***How often, how far, and in what way will product be transported? Will it be moved after initial install? How important is transportation?***

3.3 Sample Results: Interview Transcript, Customer Needs, and Specifications

Four phone interviews (two with each customer) yielded a large amount of information which was classified according to contextual factors. Table 3 shows example summary statements from the interview consolidation.

Table 3 Snapshot - Template with Sample Interview Notes

HOW: Usage Application		
#	**Context Factor**	KEY: Plain type: Template CNA Questions v3.0 ***Bold Italics: customized question for SPARC project*** • Bulleted: Interview response summary statements
a0	task application	What specific purpose(s) will product be used for? How will the product be used? ***What equipment/purpose(s) will need power?*** • Lights, dry rooms, small refrigerator for medicine, small office equipment, misc. shop equipment, and 2-way radio • AM & FM, mainly FM, computer or two, light or two, audio console • Low power means DC would be first choice • DC by itself would not be a useful system (would eventually need AC) • Long term could be medical clinic (all in remote locations) • Power Should be scalable • Should work with low water pressure (but compatible with high head)
a2	task quality	What quality of the primary function is needed? ***What are the output power requirements? What voltage/current (w/tolerances) must the product provide? Will it need "bursts" of power?*** • DC stores better, AC transfers better • Power transport from gen site to load will have to be higher voltage AC - makes most sense to integrate raft to w/ converters • Total Harmonic distortion of sine wave should be no more than 5%, preferably 2-3% • Prefer 440V 3-phase generator & rectify at end of distribution lines • Absolute maximum on efficiency not great concern - high reliability, low cost, ease of maintenance far more important (would rather double size than sacrifice reliability; ease of maintenance)
a6	task quantity	How much quantity of the product's output is needed? ***How much energy is needed for a day? What is the peak power need?*** ***Will several forms of power be needed simultaneously?*** • 5kW is a daydream (we'll take all we can get and build on that) • Don't want to go below 100W - wouldn't be usefull
a9	transportation type & amount	How often, how far, and in what way will product be transported? ***How often, how far, and in what way will product be transported? Will it be moved after initial install? How important is transportation?*** • What a single man can manage in tough terrain • Thinking of hauling up river as barge w/ motor boat • If you can pack it in we have no objection • Wouldn't be moving it at all from the initial installation site

Table 4 Snapshot – Sample Customer Needs

1. Power generation
    1.1. Multiple sources (AC, DC, multiple voltages, etc)
    1.2. Ample power
    1.3. Efficiency
2. Environment
    2.1. Protection from theft
3. Durability
    3.1. Able to be used 24/7
    3.2. Long-term use
    3.3. Able to withstand flooding
    3.4. Able to withstand lightning strikes
    3.5. Able to withstand large debris
    3.6. Can compensate for changing water levels & speeds
4. Transportability
    4.1. Light weight (HCJB 2nd or 3rd on importance)
    4.2. Compact (fit within space limitations)
    4.3. Mobility after initial setup
    4.4. Reasonable initial setup time
    4.5. Time to learn operation
5. Cost
    5.1. Low (competitive) purchasing cost
    5.2. Low maintenance cost

The customer interviews and needs served as the basis for developing the customer-driven specifications outlined in Table 5.

Table 5 Snapshot – Sample Specifications

Specification	**Description**	**Target value**
1. Easy to carry	Total weight of each component when broken down	≤ 50 lbs
2. Output voltage	Output voltage from generation system	a) 120 VAC 60 Hz OR b) 12 VDC
3. Average power	The average power from the generation system	>100W
4. Min. stream velocity	Minimum river velocity required to achieve average power	3 mph
5. Min. stream depth	Minimum operating depth required	2 ft
6. Min. stream width	Minimum operating width required	5 ft

4 Micro-hydro Design Solution

4.1 Key Design Considerations Revealed Through Contextual Needs Assessment

The contextual needs assessment templates provided the basis for a thorough, flexible, and iterative dialog with the two partner organizations. The templates facilitated recording expectations in an efficient, organized way and built a relationship with mutual understanding. The four contextual phone interviews revealed the clear design driver: provide continuous electricity ranging from 100W to 5kW to charge a battery bank, generated from a level stream with virtually no civil works. A successful design would be a rugged, easily maintainable micro-hydro solution of reasonable size and cost. Installation sites would need a minimum river speed and width for the design solution cost-competitive with solar photo-voltaic or fossil fuel generators. The relationships among stream speed, cost, and product size would need to be determined by the design team. Table 6, Table 7, and Table 8 itemize a sampling of key design considerations along with the letter-number identification of the prompt which elicited the information.

Table 6 Key Information Elicited by: Application Context Questions

Context Question Prompt#	Key Design Information
A0	Strongly desire no civil works (no head)
A2, A6	Needed power output (100W min, up to 5kW)
A2	Power needs – AC & DC
A2	Reliability & cost more important than efficiency (could make it bigger, or more)
A5	Energy storage needed (usage is 4-24 hr/day)
A7	Theft issue (disagreement between two customers)
A7	Tree barreling down stream (protect? Pull out?)
A8	Installation – river transport vs. one man pack down side of river (e.g. 50lbs) Doesn't need to be move-able

Table 7 Key Information Elicited by: Environment Context Questions

Context Question Prompt#	Key Design Information
E0	Theft (high price of copper), bug nest proof,
E3	100% humidity
E8	No idea of stream speeds, depends on how much power they can get

Table 8 Key Information Elicited by: Customer Context Questions

Context Question Prompt#	Key Design Information
C0	Setup by semi-skilled technician, clarified "throw it in the river" really means easy installation
C1	Operation super-simple, repair part needs must be minimal
C5	Don't know cost (assumption must be value-proposition)
C8	Clarified – it doesn't need to be move-able
C9	Kids jumping off, less visible is better
C10	Durability 5 years

4.2 Development of Design Solution

The design sequence was broken down into several phases. The customer needs interviews described above were conducted simultaneously with background research to provide the team a foundation of knowledge and boundaries to work within. After developing specifications based upon the interview and background information, concept generation occurred for each subcomponent, followed by feasibility assessment and selection. Once an appropriate concept was selected for each subsystem, more detailed design work was completed. This process indicated that a river wheel was the most practical solution for the stated needs of I-TEC and HCJB. Initial feasibility calculations were conducted based on the chosen concepts such as theoretical power verses paddle area in the water and the necessary cross sectional area verses river velocity for a given amount of power (see Figure 5 and Figure 6). More detailed calculations were conducted and a feasibility prototype (see Figure 7) was constructed and tested, while preliminary design work was pursued for an optimized scale model (see Figure 8).

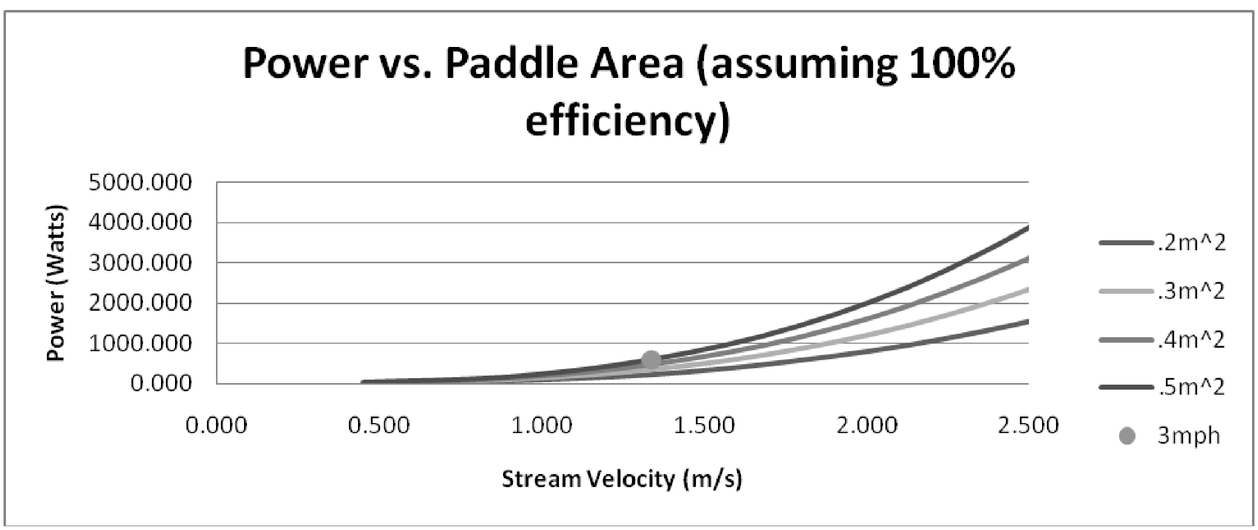

Figure 5: Kinetic Energy in a Cross Section of Flowing Water

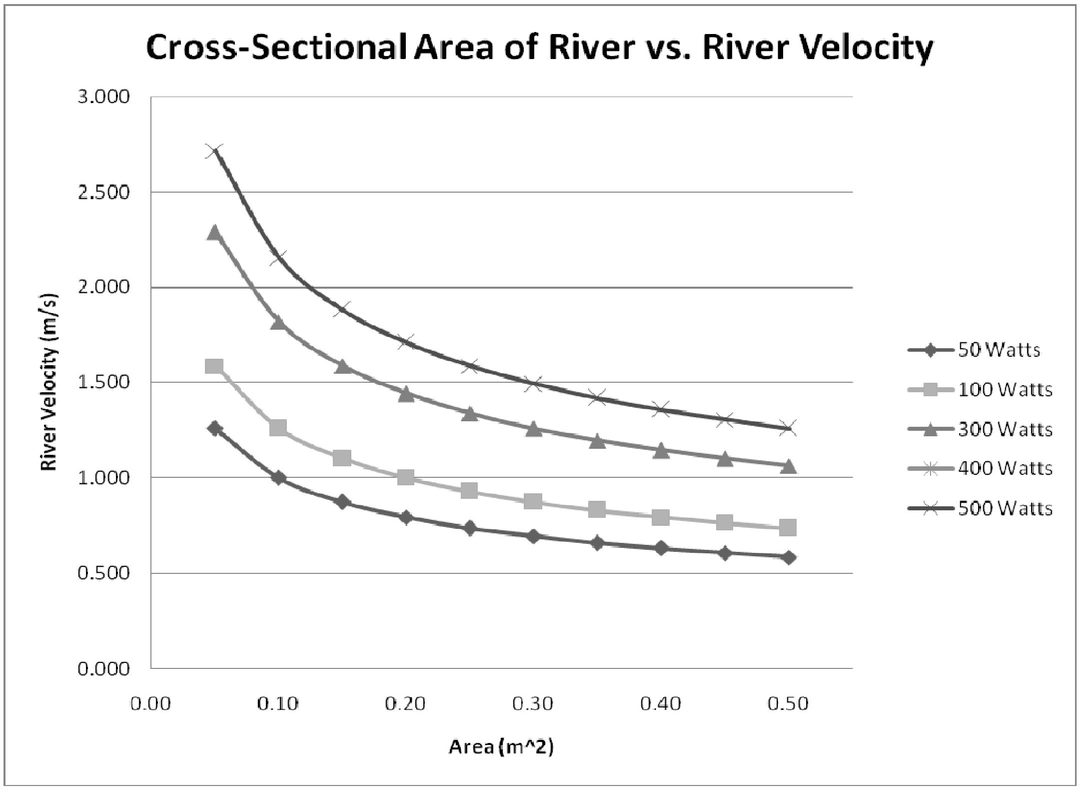

Figure 6: Kinetic Energy Iso-Power Lines for a Cross Section of Flowing Water

Figure 7: SPARC Wheel Feasibility Prototype

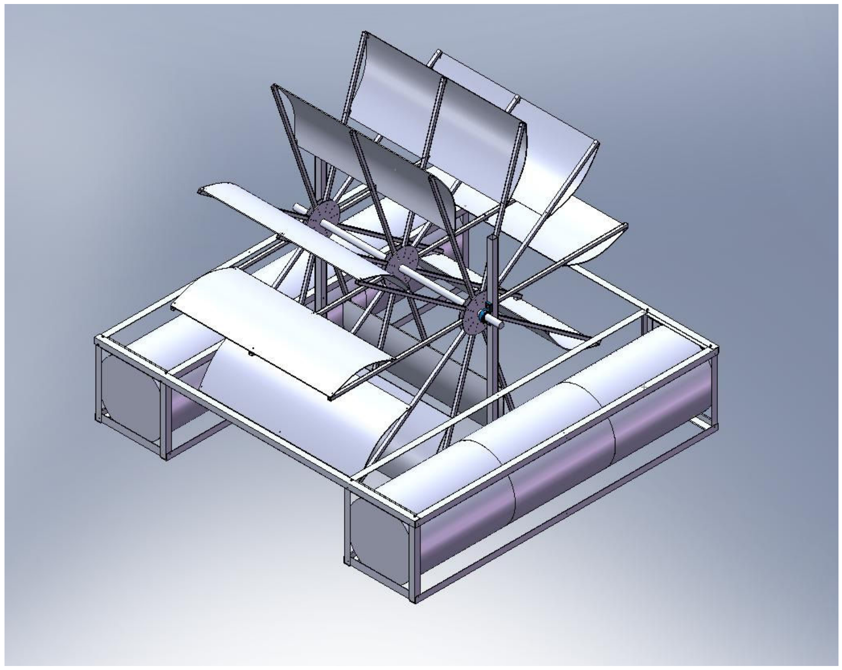

Figure 8: SPARC Wheel Preliminary Design Concept Solid Model

5 Assessment of the Contextual Needs Assessment Method: Strengths and Limitations

Rigorous assessment of the contextual needs assessment method has been reported in previous work[19], providing strong quantitative and qualitative support for the usability, usefulness, and designer acceptance of the proposed method. In an undergraduate reverse engineering class at the University of Texas at Austin, it was shown that the contextual needs assessment method could be feasibly deployed and well received, resulting in significant improvement in needs assessment. Students across fourteen teams in this UT Austin study rated the contextual needs assessment methodology of "medium-high" value for their product and an anticipated "high value" if used for a foreign product. The majority of students also rated the proposed methodology as usable and useful. Free response comments were favorable, but misunderstandings revealed the need for more thorough teaching. Three graduate teams at the same institution performing original design in a frontier context showed even more positive results. These two case study results provided strong justification for continued improvement and application of the methodology leading towards widespread dissemination in education as well as in field practice[19]. Assessment of the SPARC micro-hydro application of the contextual needs assessment method at LeTourneau University was less formal, but results were consistent with these prior studies.

Limitations of the Contextual Needs Assessment (CNA) method fall into two major categories: (1) projects which do not rely heavily on needs assessment do not make full use of CNA, and (2) projects which rely heavily on needs assessment always include risk that CNA can not completely eliminate. The first category includes projects which are not frontier to the designer, and therefore prior knowledge significantly reduces (but does not eliminate) the importance of investing resources into needs assessment. In these cases CNA is still useful, but not as critical to success since the need may already be well understood.

The second category includes projects which are frontier to the designer and rely heavily on needs assessment to correctly formulate and guide the design statement and process. These projects necessarily entail a risk that "something will be missed." The contextual needs assessment method reduces, but does not eliminate, this possibility. Needs assessment of any type is enhanced if the designers experience the actual context of use. However, in the case of the SPARC micro-hydro power design project no access to the actual end-user, environment, or application were possible (Table 9). The application of the CNA method greatly increases the chance of success of the SPARC project, but of course does not guarantee no oversights occurred.

Table 9: Map of Frontier Contexts with Dimensions of "User" and "Environment" Accessibility

	Environment Accessibility		
	Low	**High**	
User Accessibility			**High**
	SPARC Micro-Hydro		**Low**

6 Conclusions and Future Plans

Application of the modified contextual needs assessment method enabled the team to move in a few weeks from a sparse, poorly defined idea to a set of specifications accompanied with valuable contextual information. Preliminary testing is very positive, and final test data will be available soon. The project is on track for completion of a scale prototype design in May of 2008, thus establishing the theory and empirical data on which to scale and optimize future designs. The sponsoring customers are pleased with the direction and progress of the design*. The positive impacts are already apparent from the vast amount of contextual information that was efficiently and effectively gathered with the modified contextual needs assessment method.

References and Endnotes

* SPARC project results indicating the large scale required to extract sufficient kinetic energy from flowing water have prompted the customer to re-consider the possibility of using civil works and head-based hydro solutions. However, the current SPARC project scope for 2007-08 is to develop the theory and empirical data required to scale and optimize the design of water wheels which do not require civil works.

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APPENDIX A - CONTEXTUAL NEEDS ASSESSMENT QUESTIONS TEMPLATE*

HOW: Usage Application		
#	**Context Factor**	Suggested Questions v3.0 ***Customized Question (in italics)***
a0	task application	What specific purpose(s) will product be used for? How will the product be used? ***What equipment/purpose(s) will need power?***
a1	task function	What major function(s) should the product provide? ***Needed function is supplying power to regions where there is no reliable power?***
a2	task quality	What quality of the primary function is needed? ***What are the output power requirements? What voltage/current (w/tolerances) must the product provide? Will it need "bursts" of power?***
a3	task process	What is the current usage process? How will product change the current usage process? ***[skip question]***
a4	task frequency	How often will product be used? ***How often will product be used?***
a5	task duration	How long will product be used each time? ***How long will product be used each time?***
a6	task quantity	How much quantity of the product's output is needed? ***How much energy is needed for a day? What is the peak power need? Will several forms of power be needed simultaneously?***
a7	task rate	At what rate should the product perform? ***[skip question]***
a8	task ruggedness	How roughly will product be handled/treated? ***How rugged must the product be? How long does the unit need to be expected to operate between maint.?***
a9	transportation type & amount	How often, how far, and in what way will product be transported? ***How often, how far, and in what way will product be transported? Will it be moved after initial install? How important is transportation?***
a10	operator position	What physical position will the user be in (standing, sitting, hands occupied)? ***[skip question]***
a11	cleaning	How and where might the product be cleaned? ***[skip question]***
a12	Other	[Blank] ***How much can it weigh? Are there any dimension constraints?***

Table A-1: Questions Template – "How: Usage Application" Questions

* To receive or share updated and customized templates, email MatthewGreen@letu.edu.

WHERE: Usage Environment		
#	**Context Factor**	**Suggested Questions v3.0**
e0	surroundings	Where and in what type of surroundings will product be used? What in the surroundings might influence what the product must be like? ***[no change]***
e1	surroundings (sound)	How noisy are product surroundings? How much noise from the product is acceptable? ***How much can the product influence the stream appearance and turbulence? How much noise can the product make?***
e2	weather/ climate	What weather/climate will product be exposed to? ***[no change]***
e3	environment ruggedness	What objects and substances will product interact with? Will product be exposed to any unusual substances or conditions? ***[no change]***
e4	space (when in use)	How much space is available for using product? ***How much space is available for using: generator? power conditioning unit?***
e5	space (storage)	How and where will product be stored? How much space is available for storing product? ***Will the product need to have any requirements for storage? How long should it be able to lie dormit in between operations?***
e6	aesthetics of surroundings	What do the product surroundings look like? How should the product interact w/ the surrounding aesthetics? ***What do the product surroundings look like?*** ***Is how the product interacts w/ the surrounding aesthetics important?***
e7	maintenance & parts cost & availability	What is the cost & availability of maintenance & parts? **What is the cost & availability of maintenance & parts?** ***What is currently available? How long should the unit be able to run without maintenance?***
e8	energy availability & cost	What is the cost & availability of possible energy sources (human, battery, gas, electric, biomass)? ***What type of streams should this work with? (How deep, how wide, how fast, changing seasonally?)***

Table A-2: Questions Template – "Where: Usage Environment" Factors

WHO: Customer Characteristics		
#	**Context Factor**	**Suggested Questions v3.0**
c0	user	Who will use the product? (Choose? Buy?) What user characteristics affect what the product must be like? ***For wide-spread dissemination, who will use the product? (Choose it? Buy it? Implement it?) Can you think of user characteristics affect what the product must be like?***
c1	user skills & education	How skilled/experienced is the user with the task? What is the user's education level? ***How skilled/experienced is the user with the task?*** ***What is the user's education level? What format should the manual be in?***
c2	physical ability	Does the user have any physical conditions that may cause difficulty performing the task? (strength, control, range-of-motion, vision). ***Are there any possible operator physical limitations that the product needs to account for?***
c3	user tolerance for complexity	What is the most complex product the user is comfortable using? Must this product be less complex? How long is user willing to spend learning the product? ***[no change]***
c4	relevant customs and practices	Are there any cultural practices or expectations related to this product? ***[no change]***
c5	cost expectations: (purchase)	About how much is the buyer willing to pay to purchase this product? ***What are the cost limitations for purchasing the product?***
c6	cost expectations: (operation)	How much is the user willing to pay/work monthly to operate this product? ***[no change]***
c7	cost expectations: (maintenance)	How much is the user willing to pay/work monthly to maintain this product? ***[no change]***
c8	time expectations: setup & operation	About how much time is the user willing to spend to setup this product? To operate this product? How valuable is saving 1 hour of time?
c9	safety expectations	What product safety concerns does the user have? What safety features is the user expecting? What dangers must be avoided? What is the most dangerous product familiar to the user? Must this one be less dangerous? ***[no change]***
c10	durability expectations	How long does the user expect the product to last? ***How long does the user/buyer expect the product to last?***
c11	purchase context	Where and how might the product be purchased? How would the buying decision be made (research, referral, impulse)? ***In the long-run, where and how might the product be purchased (e.g. through HCJB or I-TEC?)***

Table A-3: Questions Template – "Who: Customer Characteristics" Factors