

Award Number: W81XWH-14-2-0173

**TITLE:** Efficacy Study of a Fully Implanted Neuroprosthesis for Functional Benefit to Individuals with Tetraplegia

**PRINCIPAL INVESTIGATOR:** P. Hunter Peckham

**CONTRACTING ORGANIZATION:** Case Western Reserve University  
Cleveland, OH 44106

**REPORT DATE:** October 2015

**TYPE OF REPORT:** Annual

**PREPARED FOR:** U.S. Army Medical Research and Materiel Command  
Fort Detrick, Maryland 21702-5012

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# REPORT DOCUMENTATION PAGE

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				<b>5b. GRANT NUMBER</b> W81XWH-14-2-0173	
				<b>5c. PROGRAM ELEMENT NUMBER</b>	
<b>6. AUTHOR(S)</b> P. Hunter Peckham  E-Mail: <a href="mailto:pxp2@case.edu">pxp2@case.edu</a>				<b>5d. PROJECT NUMBER</b> 0010533069-0003	
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<b>13. SUPPLEMENTARY NOTES</b>					
<b>14. ABSTRACT</b> We propose to complete a Phase II Clinical Trial to demonstrate the safety and efficacy of a fully-implanted neuroprosthesis to provide upper extremity function for individuals with cervical SCI. This study will utilize the "networked neuroprosthesis" (NNP). The NNP system is completely implanted, including all power, signal processing, stimulus generation, and electrodes. We expect that this advanced system will lead to increased regular use of the neuroprosthesis, with a subsequent positive impact on quality of life. The completion of this study will allow us to proceed to broad dissemination of advanced neuroprosthetic systems for the provision of motor function in SCI and similar diseases.					
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## 1. INTRODUCTION:

We propose to complete a Phase II Clinical Trial to demonstrate the safety and efficacy of a fully-implanted neuroprosthesis to provide upper extremity function for individuals with cervical SCI. We have completed a clinical feasibility study of a neuroprosthesis that provides myoelectrically-controlled hand grasp to this population. That device utilized external powering and processing, requiring the subjects to have assistance in donning and doffing the neuroprosthesis. We have now completed the design of a fully-implanted, modular neuroprosthetic system, the “networked neuroprosthesis” (NNP). The NNP system is completely implanted, including all power, signal processing, stimulus generation, and electrodes. This eliminates the requirement of having to wear any external components taped to the skin in order to gain hand function, which has been a requirement of all upper extremity neuroprostheses to date. We expect that these advances will lead to increased regular use of the neuroprosthesis, with a subsequent positive impact on quality of life. We have completed the development of this technology and have established a full supply chain for manufacture of this system. Recent funding from the State of Ohio has been obtained to develop this technology within the required manufacturing practices necessary for a commercial implantable medical device. In conjunction with the development of the technology, we have also developed and implemented a complete marketing strategy that is specifically targeted for implantable devices in SCI, with the NNP hand system as the first product. Thus, we are now fully equipped and prepared to conduct a Phase II clinical trial of this technology to demonstrate safety and efficacy. The completion of this study will allow us to proceed to broad dissemination of advanced neuroprosthetic systems for the provision of motor function in SCI and similar diseases.

## 2. KEYWORDS:

Neuroprosthesis  
Functional Electrical Stimulation  
Spinal Cord Injury  
Paralysis  
Rehabilitation  
Upper Extremity  
Implantable Medical Device  
Tetraplegia

## 3. ACCOMPLISHMENTS:

### What were the major goals of the project?

The major goal of the project was to implement the NNP System with 16 (ten supported by this proposal) cervical level spinal cord injured subjects and evaluate the resulting improvement in upper extremity function. Compare functional abilities with and without the use of the neuroprosthesis. The outcome assessments are designed around two hypotheses regarding the advantages of the NNP:

- #1. We hypothesize that at least 70% of all subjects will demonstrate improved function compared to their baseline performance in one or more activities (primary outcome measure).
- #2. We hypothesize that the proportion of subjects demonstrating daily usage (7 days/week) of the NNP System will be significantly higher than the published rate of daily usage for the first generation neuroprosthesis.

Project major tasks and milestones for the first twelve months of the project, showing percentage of completion as of 9/29/2015.

<b>Major Task 1: Preparations and Support for Clinical Study</b>	Months	% Completion	Notes
<b>Subtask 1: Prepare Regulatory Documents and Research Protocol</b>			
Coordinate Sites for IRB protocol submission at MHMC and LSVA	1	100%	
Submit screening protocol to IRB at MHMC and LSVA	2	100%	[1]
Assemble response for IDE application to U.S. Food and Drug Administration (FDA)	1-5	100%	
Submit IDE response	5	100%	
Finalize consent form & human subjects protocol	5	95%	
Submit implantation protocol to IRB at MHMC and LSVA	5	95%	[1]
Submit implantation protocol to HRPO	5	100%	
Assemble Clinical Events Committee	6	100%	
Submit amendments, adverse events and protocol deviations as needed	as needed		
<i>Milestone Achieved: Local IRB approval of Screening Protocol at MHMC and LSVA</i>	3	100%	[1]
<i>Milestone Achieved: IDE approval from FDA</i>	7	100%	
<i>Milestone Achieved: Local IRB approval at MHMC and LSVA</i>	6	100%	[1]
<i>Milestone Achieved: HRPO approval for all protocols</i>	7	75%	
<b>Subtask 2: Acquire Networked Neuroprosthesis Systems (NNP)</b>			
First round of purchases and assembly (3 systems)	6	100%	
Second round of purchases and assembly (3 systems)	12	25%	
<i>Milestone Achieved: NNP Systems received and sterilized</i>	7,13,17,21	25%	
<b>Major Task 2: Conduct Clinical Study</b>			
<b>Subtask1: Subject Screening</b>			
Begin subject recruitment	6	10%	[2]
Subject Screening	6-30	10%	
<i>Milestone Achieved: 1st participant consented and screened</i>	6	10%	
<i>Milestone Achieved: Study begins</i>	6	10%	
<b>Subtask2: NNP Implantation</b>			
Implant Subject #1	11	0%	[3]

Notes related to progress toward completion of project milestones:

[1] As described in QPR#1, we postponed securing IRB approval at the Louis Stokes VA (LSVA) and concentrated on MetroHealth Medical Center (MHMC) only, since it is the site where all of the surgery and follow-up will occur. The LSVA was originally identified as a referral site only, but given our long waiting list of inquiries, it is extremely unlikely that we will need any additional referrals in order to complete this project. Therefore, IRB approval at LSVA is not necessary for project completion, and only delays proceeding to HRPO submission.

[2] Although we have not begun any human studies, we have, through separate funding and separate IRB protocols, an established referral process. This process now has a significant population of potential patients, many of whom are likely to be candidates for our study. Therefore, once we are able to start recruiting and consenting subjects for this study, we anticipate the process proceeding very quickly.

[3] As described in QPR#1, there were some significant initial hurdles in our project related to obtaining regulatory approval. Although these hurdles delayed the start of implantation of the first subject, it does not delay the expected implantation of the entire cohort, and therefore we still expect to complete the project on time.

### **What was accomplished under these goals?**

The major accomplishment over the past year has been the completion of nearly all tasks required to reach the major milestone of the first implantation of the Networked Neuroprosthetic (NNP) system in human subjects. The accomplishments are in two areas: 1) regulatory and 2) technology.

1. Regulatory. We completed the submission of an Investigational Device Exemption (IDE) to the FDA during the initial portion of the year. We received conditional approval to begin the study. We have since responded to all of the identified conditions and the FDA has now provided unconditional approval to achieve the entire study cohort. This is a major accomplishment and represents the first IDE approval for a battery-powered multi-function neuroprosthesis. This initial approval helps to pave the way for future expansion of this study through supplements and additional IDE submissions.

As part of the IDE approval process, we completed numerous tests on our technology. Key testing included testing electromagnetic compatibility, current leakage, device heating during recharge, and inter-device interference. Details of the testing results are described below.

We have encountered some delays due to the unexpected requirements from the FDA relative to sterilization and biocompatibility. These are outlined in the Section 5.

2. Technology. We completed all aspects related to establishing the manufacturing, testing, and sterilization procedure for the NNP System. The system is manufactured at two primary industrial sites: Ardiem Medical, Inc., which manufactures the electrodes, network cabling, and port plugs; and Cirtec Medical, Inc., which manufactures the modules. Key components of the modules, such as the circuit, header, connector springs, and batteries, are manufactured at additional sites and assembled at Cirtec. We have established a complete sterilization protocol with iUVO, our sterilization house (formerly Ethox). They have evaluated all test articles and batch details and have signed off on all aspects of the project.

The first shipment of completed items is now in the process of sterilization. Acquisition of additional NNP components is ongoing.

Detailed accomplishments related to the testing of current leakage in the NNP System, as required by the FDA, are as follows:

**Product Characterization Test (PCT): Damaged Network Cable DC Current**

**Purpose**

To characterize DC current flow caused by a worst-case network disconnect event.

**Rationale**

The Network Cable delivers power and data to remote modules via a symmetric, <100% duty cycle, 500KHz, square wave signal. This signal, however, is not AC coupled and will deliver net DC current to tissue if left energized.

**Setup**

**Reference**

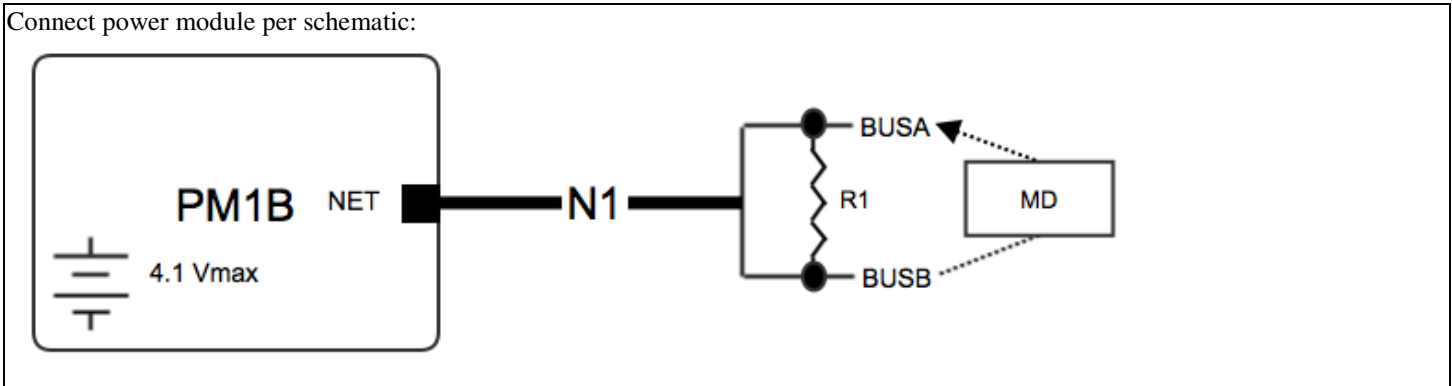
Measurement setup is derived from ISO 14708-2:2005, Clause 16.2

**Materials**

Description	MFR	MPN	SN	SW Desc	SW Ver	Note
PM1B	<a href="#">CWRU Cleveland FES Center</a>	PM1B	101	-	317	-
Voltmeter	Agilent	34401A	SG41007482	-	-	400x10 <sup>6</sup> ohm Input impedance. Set to measure DC voltage at highest resolution. A minimum of 10 seconds should pass before measurement is recorded.
Resistor, 500 ohm, 1%	-	-	-	-	-	-
4 pole LPF 14708-2	<a href="#">CWRU Cleveland FES Center</a>	<a href="#">XT-8</a>	-	-	-	-

**Connectivity**

Connect power module per schematic:



Connect the voltmeter through the XT-8 4-pole low pass filter to form the Measuring Device (MD). Connect the MD across the terminals of the 500 Ohm resistor.

## Results

MEASUREMENT	DESCRIPTION	TRIAL 1	TRIAL 2
Leakage 1	Measure voltage across 500 Ohm resistor	11.065 mV	11.061 mV
	Calculated leakage current	22 $\mu$ A	22 $\mu$ A

## Conclusion

The network will deliver 22  $\mu$ A of DC current from a chronic disconnect event. A complete or partial disconnect of any network cable has the potential to expose the subject to unacceptable AC currents. To mitigate this risk, testing is performed during the surgical procedure to assure adequate connection. Prior to critical steps in the implantation procedure, functional testing is performed on each component in a manner that allows the surgical team to assess full functionality of the unit including its network communication, and to revert to a back-up unit if the test identifies problems. Components are implanted in a distal-to-proximal order, and as each remote module is connected, a functional test is performed using a temporary network connection to confirm network communication prior to embarking on the next stage of implantation. In this way, network communication to distal modules is tested multiple times prior to the final implantation of the Power Module. A final assessment of the complete network is then tested to confirm the lack any intermittent connections that might manifest during gentle movement of the remote modules.

### *Design Verification Test (DVT): DC Leakage Current Between Modules*

#### Purpose

Measure DC current flow between modules.

#### Rationale

Running the system on battery power is highly recommended to prevent inadvertent grounding and to provide increased immunity to 60 Hz noise.

#### References

Limit derived from ISO 14708-1:2000(E) Clause 16  
Measurement setup derived from ISO 14708-2:2005 Clause 16.2

#### Acceptance Criteria

The net DC current (leakage current) of any conductive surface with direct tissue contact must be less than 1  $\mu$ A.

#### Setup

##### Materials

Description	MFR	MPN	SN	SW Desc	SW Ver	Note
PM1B	<a href="#">CWRU Cleveland FES Center</a>	PM1B	101	-	317	-
PG4D	<a href="#">CWRU Cleveland FES Center</a>	PG4D	182	-	135	-
PG4D	<a href="#">CWRU Cleveland FES Center</a>	PG4D	183	-	135	-
Voltmeter	Agilent	34401A	SG41007482	-	-	400x10 <sup>6</sup> ohm Input impedance. Set to measure DC voltage at highest resolution. A minimum of 10 seconds should pass before measurement is recorded.
10 x Resistor, 500 ohm, 1%	-	-	-	-	-	-
4 pole LPF 14708-2	<a href="#">CWRU Cleveland FES Center</a>	<a href="#">XT-8</a>	-	-	-	-

## Connectivity

Description
Wire per Schematic Bench Test 2 PG4D (See Connectivity Reference)
Connect the voltmeter through the XT-8 4-pole low pass filter to form the Measuring Device (MD).

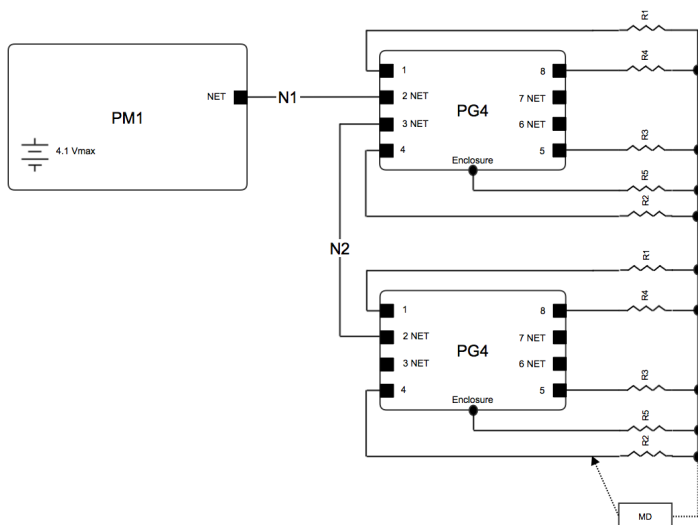
## Results

Name	Description	Pass Criteria	Unit	Trial 1	Result
Max Stim	Set stimulus to output to maximum (20 mA, 255 $\mu$ s) on every channel of every module.	-	-	-	-
PG4D182-R1	Measure voltage across R1.	< 500	$10^{-6}$ V	2	PASS
PG4D182-R2	Measure voltage across R2.			4	PASS
PG4D182-R3	Measure voltage across R3.			2	PASS
PG4D182-R4	Measure voltage across R4.			2	PASS
PG4D182-R5	Measure voltage across R5.			7	PASS
PG4D183-R1	Measure voltage across R1.			5	PASS
PG4D183-R2	Measure voltage across R2.			4	PASS
PG4D183-R3	Measure voltage across R3.			2	PASS
PG4D183-R4	Measure voltage across R4.			5	PASS
PG4D183-R5	Measure voltage across R5.			2	PASS

## Connectivity Reference

Network Map showing module and network cable arrangement for bench testing.

### Network Map





Name	Description
N1-2	Network cable should be: <ul style="list-style-type: none"> <li>• NNPS Network cable with 25cm maximum length</li> <li style="text-align: center;">- OR -</li> <li>• 2 conductor copper</li> <li>• 30cm maximum length</li> <li>• twisted pair with a minimum of 1 twist per inch</li> <li>• 26AWG minimum</li> </ul>

**What opportunities for training and professional development has the project provided?**

“Nothing to Report.”

**How were the results disseminated to communities of interest?**

“Nothing to Report.”

**Describe briefly what you plan to do during the next reporting period to accomplish the goals and objectives.**

The most immediate key milestone is obtaining HRPO approval, which we anticipate receiving in the first quarter of year 2. We will then begin completing the screening process for subjects who will be implanted in year #2. We will complete the technology acquisition for the first few subjects. Once the first subject has been implanted, the study protocol will be followed, including muscle conditioning, system programming, functional training and outcomes assessment.

**4. IMPACT:**

**What was the impact on the development of the principal discipline(s) of the project?**

**Describe how findings, results, techniques that were developed or extended, or other products from the project made an impact or are likely to make an impact on the base of knowledge, theory, and research in the principal disciplinary field(s) of the project.**

Nothing to report.

**What was the impact on other disciplines?**

Nothing to report.

**What was the impact on technology transfer?**

Nothing to report.

**What was the impact on society beyond science and technology?**

Nothing to report.

**5. CHANGES/PROBLEMS:**

**Changes in approach and reasons for change**

Nothing to report.

**Actual or anticipated problems or delays and actions or plans to resolve them**

We encountered some difficulties in the final fabrication of the NNP components, related to the IDE approval process. Specifically, it was necessary to complete some additional biocompatibility testing of one of the epoxies used in the device. This work was completed during the first six months. Although this has resulted in some early project delays related to the initiation of the first human subjects, it is not expected to delay the overall completion of the project. In addition, it was necessary to refine the design of our connector component to increase durability within the body, focusing on strengthening the strain relief in the connector. This effort was also completed during the first six months of the project. We initially targeted the first two subjects to be completed by month 14 and we now anticipate that they will be completed by month 18-22. We do not expect that this delay will alter the anticipated implantation schedule for the final cohort of subjects.

**Changes that had a significant impact on expenditures**

Nothing to report.

**Significant changes in use or care of human subjects, vertebrate animals, biohazards, and/or select agents**

Nothing to report.

## 6. PRODUCTS:

### Publications, conference papers, and presentations

Nothing to report.

### Website(s) or other Internet site(s)

Nothing to report.

### Technologies or techniques

Nothing to report.

### Inventions, patent applications, and/or licenses

Nothing to report

### Other Products

Nothing to report.

## 7. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

### What individuals have worked on the project?

PI: P. Hunter Peckham

Others:

Anne Bryden  
Brian Smith  
Kevin Kilgore  
Megan Moynahan  
Michael Keith  
Harry Hoyen  
Greg Nemunaitis  
Ron Hart  
Antonia Wilson  
Alex Campean  
Betty Dunger

### Provide the name and identify the role the person played in the project.

*If information is unchanged from a previous submission, provide the name only and indicate "no change".*

Name: Hunter Peckham

No change in role, person months, or contribution from the original submission.

Name: Anne Bryden

No change in role, person months, or contribution from the original submission.

Name: Brian Smith

No change in role, person months, or contribution from the original submission.

Name: Kevin Kilgore

No change in role, person months, or contribution from the original submission.

Name: Megan Moynahan

No change in role, person months, or contribution from the original submission.

Name: Michael Keith

No change in role, person months, or contribution from the original submission.

Name: Harry Hoyen

No change in role, person months, or contribution from the original submission.

Name: Greg Nemunaitis

No change in role, person months, or contribution from the original submission.

Name: Betty Dunger  
No change in role, person months, or contribution from the original submission.

Name: Antonia Wilson  
No change in role, person months, or contribution from the original submission.

Name: Ron Hart  
No change in role, person months, or contribution from the original submission.

Name: Mary Ann Richmond  
No change in role, person months, or contribution from the original submission.

Name: Alex Campean  
No change in role, person months, or contribution from the original submission.

**Has there been a change in the active other support of the PD/PI(s) or senior/key personnel since the last reporting period?**

**P. Hunter Peckham**

Nothing to report.

**Kevin L. Kilgore**

Two grants ended and two new grants started in the past year:

Grants ended during this reporting period:

Title: Below Injury Control of Upper Extremity Neuroprosthetic Systems (R01-NS-078789)

Ended: 8/31/2015

Title: Debilitating Contractures in Spinal Cord Injury (VAMR B7666R)

Ended: 9/30/2014

Grants started during this reporting period:

Title: "Kilohertz Frequency Alternating Current Spinal Cord Stimulation for Chronic Pain Relief" R01-NS-089530

Commitment: 2.36 Calendar-months

Funding Agency: NIH-NINDS

Grants Officer: Kip Ludwig

Performance Period: 9/1/2015 – 6/30/2019

Funding Level: \$616,673

Goals: Evaluate the use of kilohertz frequency spinal cord stimulation to alleviate chronic pain.

Specific Aims: Aim #1. Characterize KHFAC SCS treatment using existing in-vivo rat models of chronic pain. The focus of this aim will be to demonstrate the importance of a fundamental scientific understanding of KHFAC technology, KHFAC parameters, and their influence on neural structures. Through this aim, we expect to demonstrate that existing utilization of KHFAC SCS does not take advantage of its unique features (particularly conduction block), establishing the basis for significantly improved outcomes if these features can be appropriately harnessed and applied clinically.

Aim #2. Develop a computational model of the SCS and spinal roots that accurately simulates the effect of KHFAC on neural structures. Existing computational models were developed for stimulation at typical SCS frequencies (~50Hz), and do not consider the unusual response of neural tissues in the kilohertz range. Development of this model will be coupled with direct in-vivo measurements of current spread through the tissue. The model will be validated using the experimental results obtained in Aim #1.

Aim #3. The computational model developed in Aim #2 will be used to develop one or more novel prototype KHFAC SCS concepts. These prototype concepts will include the electrode locations, electrode geometries and electrode configurations that are predicted to produce specific, testable effects in the spinal cord. We will then test these prototype configurations in the in-vivo animal model to determine if these show promise as improved methods for the treatment of chronic pain. At the conclusion of this study we expect to have identified one or more novel KHFAC SCS systems ready to progress to future clinical testing.

Overlap: No scientific overlap exists between this grant and the proposed project.

Title: "Whole-body Neuroprosthetic Approach for Incomplete Cervical Spinal Cord Injury" (A1804R)

Commitment: 5.45 calendar-months

Funding Agency: VA Rehabilitation Research and Development Service

Grants Officer: Brian Schulz  
Performance Period: 5/1/2015 – 4/30/2019  
Funding Level: \$275,000  
Goals: Implement NNP system with incomplete cervical SCI, including developing a strategy for subject assessment and implementation.  
Specific Aims: Specific Aim #1 – Implement a comprehensive screening assessment strategy for the implementation of neuroprosthetics for iSCI subjects. Given the heterogeneity of the iSCI population, it is necessary to develop a systematic approach to neuroprosthetic customization, specifically with respect to the paralyzed or weak muscles to be stimulated and the voluntary muscles to be utilized as myoelectric control sources. This screening process will be used to establish the surgical implantation strategy and neuroprosthetic control algorithm for each subject. The screening procedure will include training and pre-surgical assessment of the suitability of each muscle for recording and stimulation. The overall goal is to make maximal use of all residual voluntary muscle activity in order to maximize the functional benefit for each subject.  
Specific Aim #2 – Implant a modular neuroprosthetic system in eight iSCI subjects. The control algorithm and stimulation patterns will be customized for each subject to match subject goals.  
Specific Aim #3 – Evaluate the functional outcomes and utility of implanted neuroprostheses for iSCI. Function resulting from the neuroprosthesis will be evaluated through functional testing designed to allow comparison between subjects and within subjects despite significant variability in functional ability. Embedded device datalogging will be used to evaluate the regular home/community use of the specific functions provided by the neuroprosthesis.  
Specific Aim #4 – Gain preliminary data regarding neuroplastic recovery of voluntary function secondary to neuroprosthetic intervention in iSCI. Daily use of weak voluntary musculature may result in strengthening of weak or latent connections in the spinal cord. We will evaluate whether there is any evidence of such recovery of function through measurement of muscle strength over time.

Overlap: No scientific overlap exists between this grant and the proposed project.

Title: Evaluation of percutaneous electrodes for direct current nerve block  
Commitment: 0.44 Calendar-months  
Funding Agency: Case Coulter Technology Transfer Program  
Grants Officer: Steve Fenning  
Performance Period: 9/1/2015 – 8/31/2016  
Funding Level: \$100,000  
Goals: Evaluate the possibility of chronic nerve block using a percutaneous electrode next to a peripheral nerve.  
Specific Aims: Our recent acute in-vivo experiments, under Coulter Foundation funding, using charge-balanced direct current (CBDC) nerve conduction block with a percutaneous electrode design, have been very successful. The key goal of the present proposal is to evaluate the efficacy of repeated CBDC nerve block in a chronic in-vivo model, delivered through percutaneous electrodes, without producing adverse permanent effects on nerve conduction. We will fabricate high charge capacity percutaneous electrodes, implant them in test animals and evaluate results of repeated nerve block over three weeks, functionally and histologically. The key commercial goals include expanding IP protection to include specific clinical targets, disseminate experimental results, obtain crucial data for future funding, and begin discussions with potential licensing partners. The strategy for commercialization beyond this Coulter project includes performing in-vivo and first-in-man studies targeted to specific clinical applications of CBDC. We anticipate that block of chronic peripheral nerve induced pain is an attractive first human application (combination of a large market and the simplest implementation requirements).  
Overlap: No scientific overlap exists between this grant and the proposed project.

#### **Michael W. Keith**

One grant ended in the past year:

##### Grants ended during this reporting period:

Title: Below Injury Control of Upper Extremity Neuroprosthetic Systems (R01-NS-078789)  
Ended: 8/31/2015

#### **Harry A. Hoyen**

Nothing to report.

#### **Greg Nemunaitis**

Nothing to report.

**Mary Ann Richmond**

Nothing to report.

**Megan Moynahan**

One grant started during the past year.

Grants started during this reporting period:

Title: Commercialization of an Innovative Neuromodulation and Neurostimulation Technology Platform - 12-220  
 Commitment: 4.2 calendar-months  
 Funding Agency: Ohio Department of Development, State of Ohio  
 Grants Officer: Anthony Howard  
 Performance Period: 06/01/13-05/31/17  
 Funding Level: \$982,967  
 Goals: The goal of the “Neuromodulation and Neurostimulation Technology Platform Program” (the NNT Program) is to bring to market a revolutionary implantable neurostimulation platform system called the OMNISTIM™ System.  
 Overlap: No scientific overlap exists between this grant and the proposed project.

**Anne Marie Bryden**

One grant started during the past year.

Grants started during this reporting period:

Title: “Whole-body Neuroprosthetic Approach for Incomplete Cervical Spinal Cord Injury” (A1804R)  
 Commitment: 6 calendar-months  
 Funding Agency: VA Rehabilitation Research and Development Service  
 Grants Officer: Brian Schulz  
 Performance Period: 5/1/2015 – 4/30/2019  
 Funding Level: \$275,000  
 Goals: Implement NNP system with incomplete cervical SCI, including developing a strategy for subject assessment and implementation.  
 Specific Aims: Specific Aim #1 – Implement a comprehensive screening assessment strategy for the implementation of neuroprosthetics for iSCI subjects. Given the heterogeneity of the iSCI population, it is necessary to develop a systematic approach to neuroprosthetic customization, specifically with respect to the paralyzed or weak muscles to be stimulated and the voluntary muscles to be utilized as myoelectric control sources. This screening process will be used to establish the surgical implantation strategy and neuroprosthetic control algorithm for each subject. The screening procedure will include training and pre-surgical assessment of the suitability of each muscle for recording and stimulation. The overall goal is to make maximal use of all residual voluntary muscle activity in order to maximize the functional benefit for each subject.  
Specific Aim #2 – Implant a modular neuroprosthetic system in eight iSCI subjects. The control algorithm and stimulation patterns will be customized for each subject to match subject goals.  
Specific Aim #3 – Evaluate the functional outcomes and utility of implanted neuroprostheses for iSCI. Function resulting from the neuroprosthesis will be evaluated through functional testing designed to allow comparison between subjects and within subjects despite significant variability in functional ability. Embedded device datalogging will be used to evaluate the regular home/community use of the specific functions provided by the neuroprosthesis.  
Specific Aim #4 – Gain preliminary data regarding neuroplastic recovery of voluntary function secondary to neuroprosthetic intervention in iSCI. Daily use of weak voluntary musculature may result in strengthening of weak or latent connections in the spinal cord. We will evaluate whether there is any evidence of such recovery of function through measurement of muscle strength over time.  
 Overlap: No scientific overlap exists between this grant and the proposed project.

**What other organizations were involved as partners?**

Nothing to Report.

**8. SPECIAL REPORTING REQUIREMENTS:**

QUAD CHART: In appendix.

## Efficacy Study of a Fully Implanted Neuroprosthesis for Functional Benefit to Individuals with Tetraplegia

SC130252

W81XWH-14-2-0173

PI: P. Hunter Peckham

Org: Case Western Reserve University, Cleveland, OH

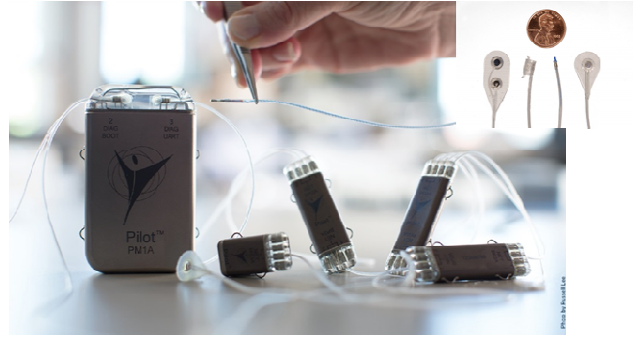
Award Amount: \$2,363,423

### Study/Product Aim(s)

•Task #1 – Implement ten cervical level spinal cord injured subjects and evaluate the resulting improvement in upper extremity function. Compare functional abilities with and without the use of the neuroprosthesis.

### Approach

The outcome assessments are designed around two hypotheses regarding the advantages of the Networked Neuroprosthesis (NNP): #1. We hypothesize that at least 70% of all subjects will demonstrate improved function compared to their baseline performance in one or more; and #2. We hypothesize that the proportion of subjects demonstrating daily usage of the NNP System will be significantly higher than the published rate of daily usage for the first generation neuroprosthesis.



Accomplishment: Regulatory approval obtained from FDA; IRB approval nearing completion. First systems acquired (as shown above). All received systems have been fully tested and have been sent for sterilization. Additional acquisitions in Q1, Y2.

### Timeline and Cost

Activities	PY	1	2	3	
Regulatory and Administrative					
Technology Acquisition					
Implantation of NNP					
Assessment of Outcomes					
Estimated Budget (\$K)		\$792	\$446	\$262	\$000

Updated: Oct. 30, 2015

### Goals/Milestones (Example)

**PY1 Goal – Complete Regulatory; Acquire first systems, First implant**

IDE

Acquire first systems (~30% complete – pending IRB approval)

**PY2 Goals – System Implantation and Evaluation**

Acquire technology

System Implantation

System Evaluation – Functional Assessments

**PY3 Goal – System Implantation and Evaluation**

System Implantation

System Evaluation – Functional Assessments

### Comments/Challenges/Issues/Concerns

- Significant hurdles in obtaining FDA regulatory approval related to additional requirements for extensive testing – early delay.
- Delay in first surgery – still expect to complete project in 3 years.

### Budget Expenditure to Date

Projected Expenditure: \$792K

Actual Expenditure: \$450K (delay in system acquisition)