***Triple Helix XI**: International Conference on University-Business-Government Co-innovation. London, 7-10 July 2013*

Impacts for Social-Value Stakeholders in Industry-University-Government Cooperation: Case Study of CChIPS' Impact on Child Injury Prevention

Author Name	Author Name	Author Name
Affiliation Name	Affiliation Name	Affiliation Name
Contact Info	Contact Info	Contact Info

Abstract

Many government-industry-university (*"triple helix"*) cooperative research centers (CRCs), and most Industry / University Cooperative Research Centers (I/UCRCs) sponsored by the U.S. National Science Foundation (NSF), conduct pre-commercial research on technologies of interest to stakeholders in specific industries. Few NSF I/UCRCs have dual missions explicitly combining scientific research with action via application of the results toward advancing broad, societal values of interest to external constituencies. Here we present an 8-year case study analyzing the impacts of one social-value-oriented NSF I/UCRC, the *Center for Child Injury Prevention Studies (CChIPS –http://cchips.research.chop.edu)*, which researches children's injuries (#1 source, automobile crashes) and provides the scientific foundation for active interventions, policies, and public education, and promotes injury prevention. The case history sets up a 2-part analysis of outcomes and impacts using an open systems / "logic model" approach, focusing first on key stakeholders – member organizations – and R&D-related outcomes critical to sustaining a technology-oriented I/UCRC, and second on outcomes for external constituencies relevant to the larger mission of child injury prevention: industry, scientific, and professional associations with interests in children's safety and focal beneficiary groups: children, teen drivers, and parents. We describe examples of CChIPS innovative, interactive products related to child injury prevention for members and for external constituencies, some of which are potentially adaptable in other, social-value-oriented CRCs.

Key words: Impact analysis; Cooperative research center; innovation; case study; logic model; I/UCRC.

The authors acknowledge financial assistance provided by the University of [Location], in preparing and presenting this paper. The authors acknowledge the Industrial Advisory Board Member companies of the Industry/University Cooperative Research center, Center for Child Injury Prevention Studies (CChIPS), and U.S. National Science Foundation (NSF) for financial support of this study.

Introduction

With rapid, global expansion over the past two decades in the number, variety, and complexity of government-industry-university – "*triple helix*" – cooperative research centers (CRCs; Boardman & Gray, 2010; Etzkowitz, 2008; Gray, Boardman & Rivers, 2013), the challenges of evaluation and impact analysis have also grown more complex (Feller, Chubin, Derrick & Pallavi, 2013; [Authors,] 2010). Many government-industry-university (CRCs) conduct pre-commercial research on technologies of interest to stakeholders in specific industries. Few CRCs explicitly add to their research missions a component of action to apply their research in a value-driven agenda of interest to wider, external constituencies, like governments and their agencies; industry and professional associations; consumers, and others. Such *social-value-oriented* Centers represent *multi-purpose* CRCs (Feller *et al.,* 2013) with dual missions of research of interest to primary shareholders and application of the findings to advance causes of interest to external constituencies, with potential economic impacts (Roesener, Manrique & Park, 2013) and broader, national impacts.

As an initial step toward developing an approach to understanding impacts of a dual-mission, social values-oriented CRC, we use a case study to analyze outcomes and impacts for key stakeholders and external constituencies of a single Center. The case study approach (Yin, 2002) follows established practice in evaluating R&D organizations and analyzing their impacts (Ruegg & Feller, 2003), and builds on recent case studies of industry-university cooperative research centers ([Authors,] 2011; [Authors,] 2013).

Our case study focuses on an exemplar social-values oriented CRC, the *Center for Child Injury Prevention Studies (CChIPS;* http://cchips.research.chop.edu*),* starting its 9th year operating from The Children's Hospital of Philadelphia (CHOP) and University of Pennsylvania (Penn), with a second research site at The Ohio State University Wexner Medical Center (OSU). One of 60+ Industry / University Cooperative Research Centers (I/UCRCs) sponsored by the United States (U.S.) National Science Foundation (NSF), CChIPS seeks to *"advance child safety through evidence and action,"* via a pre-competitive research program on children's injuries (#1 source in the U.S.: automobile crashes) by translating scientific findings into "commercial applications, interventions, policies, and public education programs for prevention."

The case study has four sections, starting with the context: the NSF I/UCRC Program. Second, we trace the history and development of CChIPS since inception in 2005, focusing on its mission and primary stakeholders (member organizations), programs of scientific research and engagement with wider, external constituencies in service of the broader mission of promoting children's safety and injury

prevention. Third, we analyze CChIPS' outcomes and impacts, applying a version of open systems analysis pioneered by Katz and Kahn (1966), later extended to evaluating organization effectiveness (Daft, 2007), and to program evaluation (McLaughlin & Jordan, 2010), where the term "logic model" refers to the framework used here. We apply this analysis first to CChIPS at the organization level, then at the at the stakeholder level. Fourth, we describe examples of CChIPS' innovative outputs, including products and events aimed at fostering beneficial outcomes for member organizations and external constituencies potentially adaptable in other, social-value-oriented CRCs.

Context: U.S. NSF I/UCRC Program

The U.S. NSF I/UCRC Program (http://www.nsf.gov/eng/iip/iucrc) is perhaps the oldest and largest public sponsor of government-industry-university cooperative research centers (Gray, Boardman & Rivers, 2013). NSF offers annual seed-grants renewable up to 15 years for I/UCRCs conducting pre-commercial, primarily industry-funded research on selected technologies. In essentially a franchising arrangement, I/UCRC member organizations sign a now-standard membership agreement with host universities / institutions defining their relationships, including guidance of the cooperative research agenda and intellectual property rights. NSF expects I/UCRCs to follow governance and management procedures developed over 30+ years (Gray & Walters, 1998). NSF requires each I/UCRC to hold semi-annual meetings of its Industry Advisory Board (IAB; representatives of member organizations); university participants (staff, scientists, graduate students) and NSF representatives to review and plan the research. NSF provides oversight, independent evaluation (Gray, 2008), and annual, national conferences for organizational learning and dissemination of best practices. Since 1982 NSF launched 155 Centers. In 2010 a total of 70 I/UCRCs had "graduated" and no longer received NSF funds; two thirds of the graduated I/UCRCs (*n*=45) were still operating self-sufficiently (McGowen, 2010).

In 2012 NSF sponsored 57 I/UCRCs with 1,093 industry and government memberships and research programs involving 929 faculty scientists; 174 post-doctoral associates; and 1,766 graduate students in all. The average I/UCRC in 2011-12 had 2 or 3 research sites; 20 members; a $2.4M annual budget; 17 faculty scientists; 3 post-docs and 31 graduate students, and produced 33 conference presentations, 24 publications, and 11 graduate degrees in 2011-12 (Gray, DeYoung & McGowen, 2013).

Most NSF I/UCRCs seek to develop specific, innovative pre-commercial technologies. Examples of technology-oriented I/UCRCs operating in 2013 are researching biophotonic sensors, surfactant systems, meta-materials, and smart vehicle systems, generally serving stakeholders in closely related industries. Few NSF I/UCRCs have a dual mission combining fundamental research plus an explicit action agenda advancing a broad, societal value of interest to external constituencies, as CChIPS has.

History & Development of *CChIPS, Center for Child Injury Prevention Studies*

The Center for Child Injury Prevention Studies opened in 2005 with a NSF 5-year renewable I/UCRC Award at host institutions CHOP and Penn, with leadership by founding Director Flaura Koplin Winston MD, PhD. Start-up followed two years of planning and meetings of prospective, initial stakeholders in industry, government (NSF), and host research institutions. After a 2004 Center planning conference involving representatives of all primary stakeholders, six founding industry member organizations – three automobile manufacturers; one child restraint manufacturer; one automobile safety restraint system supplier; and one national insurance company – signed the membership agreement, paid dues, and became the charter Industry Advisory Board (IAB). The founding Director, IAB, and scientists cooperated to articulate the CChIPS goal for its first press release in 2005: "providing a national platform for cooperative industry-university research on child injury prevention science and engineering."

In its first year as an I/UCRC, 2005-06, CChIPS began a cooperative R&D program proposed by Center scientists, selectively funded by consensus of the IAB, and executed by science teams incorporating graduate and undergraduate students at facilities of host institutions. To ensure applicability of the research to safety innovations, each project had at least one industry mentor from the IAB. Projects addressed five themes: 1) injury biomechanics, mechanisms, and tolerance; 2) design, development, and testing of injury prevention technologies; 3) human, safety-related behavior and interaction with safety-related technologies; 4) education and promotion of safety; and 5) evaluation of safety programs. Semi-annual Center meetings included project presentations by scientists; poster sessions with the students; informal networking receptions; dinners with invited speakers; and closed-door IAB sessions.

For its second year, 2006-07, CChIPS retained all charter members and added two new members: a second child restraint manufacturer and first U.S. government agency non-voting member. They had access to CChIPS' new, secure, members-only website. The annual membership growth of 33% was unusual for an I/UCRC that year. In the I/UCRC Program in 2006-07 the average Center had an annual attrition in membership of 16%, a loss of about 1 of every 6 members (Gray & McGowen, 2008).

By the second year the IAB showed a level of cohesion typical of longer-lived Boards. Most member organizations sent the same one or (usually) two individuals as representatives. Many knew one another from industry forums and professional and scientific conferences. They cooperated to develop CChIPS' operating principles (bylaws) and policies, made consensus decisions on research proposals from Center scientists, and worked closely together on project funding. Board meetings often had full attendance.

By 2008 CChIPS had expanded outreach to external constituencies. Besides a members-only research website (http://cchips.research.chop.edu), through its parent center at CHOP, the Center for

Injury Research and Prevention, the Center developed and maintained four public websites that translated research evidence into consumer guidance, risk information, and preventive action, for parents and others. The websites addressed child injuries (https://www.chop.edu/injury); car-seat safety (http://www.chop.edu/carseat); teen driver safety (http://www.chop.edu/youngdrivers); and caring for an injured child (http://aftertheinjury.org).

In the economic recession of 2008 CChIPS temporarily lost one member to internal budget cuts. In response, the CChIPS IAB revised its bylaws to include a "technical advisor" role to enable the departing member representative to keep attending Board meetings. Other members were granted temporary hardship reductions in their dues so they could retain membership.

In 2008 two senior CChIPS faculty research scientists took jobs with CChIPS member organizations. This was unusual in the I/UCRC Program, where Center members more often hire graduating PhDs. CChIPS developed an External Investigator Program and began inviting proposals from scientists who brought at least one member organization to CChIPS. In this way, Ohio State University gained experience with CChIPS before establishing the second site.

As the recession continued (2008-10) CChIPS maintained its membership at a time when many NSF I/UCRCs lost members, refined its research operations and scientific portfolio, and initiated more external collaborations and outreach. CChIPS' members continued to renew, providing funding for a research portfolio of 8 to 10 cooperatively funded projects. A 2008 cooperative CChIPS project with Monash University (Australia) and with the Beijing Centers for Disease Control and Prevention involved research to determine whether a U.S.-developed intervention to address low booster seat use among young children would be appropriate for families in Beijing, China, where awareness of child safety seats and their use was low. One CChIPS member, a restraint supplier, donated and exported booster seats to China and translated the operating manual into Mandarin for the study. The intervention proved very successful. CChIPS scientists conducted other large studies sponsored by IAB members, including release of a national report on teen driving (2008) and a cooperative, national Young Driver Research Initiative (2009). In addition, CChIPS collaborated with the Association of International Automobile Manufacturers, which helped fund a CChIPS report on children's injuries in car crashes.

By 2009 CChIPS members included four organizations specializing in child safety equipment who were interested stakeholders when questions were raised about a 2007 article in a national publication reporting tests and ratings of automobile child restraint systems, published by an independent product testing organization. Tests for the 2007 report were developed with limited industry involvement (as for other products tested by the organization). A cooperative dialogue was facilitated via the industry-

university-government forum offered by CChIPS on improving the testing protocol. (Later the testing organization joined CChIPS.) In 2012, a new protocol developed with joint insight was proposed.

In 2009 CChIPS also collaborated with another NSF I/UCRC, Center for Autonomic Computing (University of Florida) in an NSF-funded project to develop and demonstrate an innovative technology, a tele-center for remote, collaborative review of children's injuries in motor vehicle crashes. This technology enabled: 1) distributed, asynchronous collection of digital content needed for crash case reviews, with consistent organization of content across cases; 2) secure, Web-based, remote participation in case review meetings with multi-media sharing of case content via visual images, real-time written and oral communication, and use of Web resources; and 3) archiving for post-review access and follow-up involving statistics, search, networking, and other forms of remote image-sharing and collaboration. Additional supplemental funding in later years allowed for the adaptation of this IT appliance to the remote collaboration for local multidisciplinary child fatality reviews ([Authors], 2012).

In its fifth year (2009-10), CChIPS neared completion of preparations for a new research site at Ohio State University (OSU), and prepared a proposal to NSF for a second (Phase II), 5-Year Renewable I/UCRC Award, which was funded in 2010. Table 1 below shows 9 members for the year, including an automobile manufacturer that joined ahead of others soon to affiliate at the new OSU site.

Table 1. CChIPS I/UCRC Sites, Members & Member Funding by Years, 2005-13

Years	I/UCRC Sites	# Member Organizations	Member Funding	Research Projects
2005-06	1	6	$300,000	7
2006-07	1	8	$375,000	9
2007-08	1	9	$425,000	8
2008-09	1	8	$425,000	8
2009-10	1	9	$400,000	10
2010-11	1	12	$505,000	11
2011-12	2	13	$505,000	9
2012-13	2	20	$835,000	10

In CChIPS' sixth year, 2010-11, the Center made three important advances. First, the leadership, IAB, and faculty scientists together undertook a strategic review for the Center's second 5 years as an I/UCRC with the expected, second university site, developed a "logic model" as a framework, updated the mission statement and research agenda, and identified new tactics for external outreach. Second, CChIPS gained three new members: a manufacturer of child restraints, anticipating the OSU site; another automobile manufacturer; and the first small business affiliate member, a firm specializing in driving simulation. Third, CChIPS expanded external engagement, with bi-monthly release of electronic news-letter with a summary of relevant literature and enhanced websites. CChIPS also successfully hosted its

first pubic, international workshop (2010) "The Future of Side Impact Protection for Children," and first international, professional conference (2011), Advances in Child Injury Prevention (ACIP), in Plymouth, Michigan (with 83 attendees from 37 organizations). CChIPS hosted the ACIP conference again in both 2012 and 2013 with rising attendance with the dual aim of bringing CChIPS and other child safety evidence to auto safety engineers and raising additional capital to offset growing administrative costs of running CChIPS. Several CChiPS member companies provided financial sponsorship of the conference.

After the CChIPS - OSU site received its NSF I/UCRC award and opened in 2011, membership grew to 20 organizations within two years, including several new kinds of organizations. Members joining in 2011-12: the sole producer of crash test dummies worldwide; and a second small business member, focused on development of medical and safety technology. In 2012-13, the member lost to the economic challenges of 2008 rejoined, and the IAB included all charter members. Also joining in 2012-13: another automobile manufacturer; another manufacturer of children's safety equipment; the first non-profit (non-voting) member, a product testing & information organization; a third small business, specializing educational and training programs; and a vehicle test facility.

In 2011 CChIPS emphasized another form of external engagement: engineering guidelines for evidence-based design of child safety equipment. Using in-depth crash investigation databases (Crash Injury Research and Engineering Network & Partners for Child Passenger Safety Study) CChIPS scientists examined crashes involving rear-seated, CRS-restrained children ages 0 to 8 years in side impact crashes who sustained clinically important injuries. Analysis revealed the most common injuries involved the skull and brain. Findings suggested simple, specific design changes in child restraints (side wings and energy management features) to mitigate or prevent many of these injuries.

By the end of its 8th year (2012-13) CChIPS had integrated the OSU site, expanded the cooperative research agenda, retained all members, continued earlier forms of external engagement and international partnering, and explored others. One new member joined for 2013-14, a second non-profit research organization focused on pediatric trauma, operating from Wake Forest University, a prospective future university site for CChIPS.

Today most CChIPS members –13 of 21 – are large, for-profit organizations with internal R&D units: 7 auto-makers; 4 manufacturers of child safety equipment; 1 vehicle restraint supplier; and 1 insurer. The other 8 consist of government or non-profit organizations or small, private businesses.

CChIPS Stakeholder Outcomes & Impacts for Member Organizations External Constituencies

Impact and outcome analysis for CChIPS draws on *open systems* analysis*,* pioneered by Katz and Kahn (1966), later routinely applied to organizational change and development (Cummings & Huse, 1989) and evaluation of organizational effectiveness (Daft, 2007; Jones, 2013). Applications to program evaluation (Mclaughlin & Jordan, 2010) refer to flow-charts incorporating this approach, or "*logic models*." Organization-level analysis frames a finer-grained analysis at the stakeholder level, focusing on CChIPS member organizations and external constituencies.

Organization-Level Analysis

Open systems / logic model analysis depicts a cycle of repeated exchanges of an organization with its larger environment in a deceptively simple flow diagram built around an input-throughput-output sequence showing external entities and/or events before and /or after, for example:

Inputs –> Processes –> Outputs –> Outcomes –> Impacts

"*Impact*" refers to a long-term, whole-system (organization-wide), external result. For CChIPS, key external impacts involve children's safety, for instance as shown in national, annual rates of children's injuries in auto crashes and related results such as reductions in injury severity, teen driver crash rates, etc. Incremental influences of CChIPS programs on national children's safety-related statistics may occur, for example, through Center-inspired improvements in children's booster seat designs, increased rates of teen seat-belt use, or enhanced parents' knowledge of teen driving risks. For the continuing, downward national trend in child motor vehicle injury and fatality rates (*"Traffic Safety Facts: 2011 Data,"* 2013), CChIPS stakeholders at least take pride, if only a share of credit.

Evaluation of an I/UCRC like CChIPS by government sponsor NSF emphasizes R&D-related impacts, such as technology transfer and creation of economic value (Gray, 2008). Impact could start, for instance, if Center research stimulated a research idea by a member representative, who proposed a proprietary research project, got the project funded in the member organization (an outcome for that stakeholder), where it yielded a new product design (medium-term outcome), which produced a technology breakthrough, later developed in a profitable start-up company (impact), and/or resulted in a product design that dramatically reduced an industry's energy costs (broader, longer-term impact). This hypothetical sequence illustrates actual impacts of NSF I/UCRCs documented, for example, by Scott & Graube (2012). The long, complex chain of low-probability events (e.g., only a small fraction of business start-ups last 5 years; Bhide, 2000) suggests that a system has to generate many outputs to have impact.

For any I/UCRC, certain short-term outcomes remain critical to continued operation, notably membership renewal and growth. Center research products ideally motivate member organizations to renew their memberships and pay dues (inputs to the Center), which fund the next year's research in the repeating cycle depicted in open systems theory. CChIPS fared well on these short-term outcomes, with membership gains in 7 of 8 years (Table 1). The gains suggest that members saw sufficient benefit from outcomes of Center membership to their organizations to justify continued, annual investments.

Other critical, short-term, organization-level outcomes for CChIPS involve NSF and host institution stakeholders: the annual renewal of the NSF I/UCRC award (which depends on meeting minimum membership requirements), and scientific resources from host institutions (CHOP, Penn, and OSU). Among host institution stakeholders most critical for CChIPS are faculty scientists, and their decisions to submit new project proposals each year for continuing or new projects. Scientific projects conducted in host institution facilities with assistance of graduate and undergraduate students also depend on continued participation of students, for whom the host universities may (or may not) provide funding for tuition and assistantships, office space, etc. Hosting contributions by university stakeholders (outcomes for CChIPS that translate directly into inputs for the next year's operations) in turn depend on stakeholder outcomes for host institutions, such as research publications; research grant proposals; research grants and contracts; degrees awarded; and student job placements.

In brief, an organization-level open systems / logic model analysis indicates that 1) some outcomes of research and outreach programs have potential, incremental external impacts related to CChIPS' dual mission; and 2) some short-term stakeholder outcomes have impacts critical to CChIPS' continued operation, notably renewal by industry members and resources from host institutions. These differ for the government, university, and industry stakeholder groups – and differ among specific stakeholders.

Stakeholder Outcomes for CChIPS Member Organizations

Stakeholder outcome / impact analysis for member organizations calls for a variation of the open systems / logic model sequence that differentiates recipients (usually customers) of system outputs:

Inputs–>Processes–> Outputs –> ***Stakeholders –> Stakeholder Outcomes*** *–> [Center]* ***Outcomes*** *–> Impacts*

Stakeholder outcomes for each member organization come from receiving Center output(s), and can influence or determine Center outcomes, notably member renewal. ("*Impacts*" refer to follow-on results.)

NSF I/UCRC Evaluation Program assessment of member outcomes. Since the 1980s the NSF I/UCRC Evaluation Program has assessed collective member outcomes annually via the NSF *Industry Questionnaire* (Gray, DeYoung, Leonchuk & McGowen, 2012). Relevant items used through 2011 asked

about outcomes related to R&D, including commercialization and professional networking, as shown in Table 2 (next page). Also tabulated are responses by CChIPS member representatives and responses from all participating I/UCRCs in 2007 (CChIPS' 3rd year) and 2011 (CChIPS' 6th year). Of note, CChIPS had relatively high response rates (100% & 85% of members, respectively) in comparison with national response rates (48% & 39%). The table shows that in 2007 and 2011 CChIPS member representatives, as a group, reported beneficial, R&D-related outcomes that closely paralleled those concurrently reported at other NSF I/UCRCs. (Results for CChIPS were similar in other years with different versions of the questionnaire, pre-2007 and post-2011.) Also, compared with other NSF I/UCRCs, CChIPS members reported greater benefit from outcomes identified with networking.

Table 2. CChIPS 2007 & 2011 Responses to NSF Industry Questionnaire Items on Member Benefits

• During the past year, to what extent has participation in the center contributed to the following benefits for your organization? 1 = No Impact … 3 = Moderate Impact … 5 = Very High Impact	2007		2011	
	CChIPS (N = 9)	NSF I/UCRCs (N = 266)	**CChIPS** (N = 11)	NSF I/UCRCs (N = 360)
a. **Research & Development:** Enhanced via increased technical awareness, accelerated or new projects or development of intellectual property in my organization.	**3.1**	3.2	**3.1**	3.0
b. **Commercialization:** Enhanced via improved or new products, processes, services, improved sales, or new or retained jobs.	**2.1**	2.3	**2.6**	2.0
c. **Professional Networking:** Enhanced via improved ability to recruit students, increased cooperation with other industrial members and scientists outside my organization.	**3.9***	3.5	**3.6***	3.2

*$p < .05$ Difference between Center mean (unit weights, 1 through 5) and national mean, based on 2-tailed univariate ***z***-tests.

Stakeholder R&D-related outcomes mentioned in the survey items shown in Table 2, when listed separately, expand to about a dozen. These represent a subset of at least 27 potential R&D outcomes for I/UCRC member organizations, listed in Table 3, including others drawn from prior research (Boardman *et al.* 2013; Gray & Steenhuis, 2003), the 2012 revision of the NSF *Industry Questionnaire* (Gray, DeYoung & McGowen, 2013), and a few outcomes suggested by I/UCRC member representatives.

Only a subset of stakeholder R&D-related outcomes listed in Table 3 applies to any one CChIPS member. A majority of CChIPS members consists of large manufacturing or service firms for which all 22 outcomes in the first three categories may apply, such as Center-stimulated, internal R&D. In 2012, for example, 11 member representatives (of 20 invited) answered the *Industry Questionnaire*, and 9 responded to questions on internal R&D projects stimulated by Center research. Three members reported a combined investment of $350,000 for the year in Center-stimulated projects. Possibly some members who did not respond were organizations with internal R&D operations that incorporated Center-stimulated projects; maybe some respondents chose not to disclose internal R&D projects. Even so, only a minority of CChIPS members likely benefited from Center-stimulated R&D projects within their organizations.

Table 3. Stakeholder R&D Outcomes for All I/UCRC Members & 3 Kinds of Member Organizations

I/UCRC Members	Stakeholder R&D-Related Outcomes for I/UCRC Member Organizations
All Member Organizations	• ***Leveraged R&D investment:*** Access to lower-cost research portfolio than internal / contract • ***Technical knowledge transfer****:* Scientific findings, procedures, failures, testing methods... • ***Scientist relationships*** with nationally recognized Center specialists; informal consultation... • ***Recruiting*** Center-trained students & scientists as interns and/or employees • ***Networking****:* Industry / professional contacts, relationships, exchanges with members of competitor, customer, supplier, and/or other organizations. • ***Collaboration****:* Cooperation with industry scientists, practitioners from other organizations on Center projects and joint projects with other Centers & research partner organizations • ***Professional development:*** IAB representative scientific / technical knowledge & capability • ***Leadership development*** in Board Chair / research liaison / group leader roles • ***Proprietary contract research projects*** with Center / affiliated scientists • ***Intellectual Property*** if developed at the Center, if the organization shares costs (unusual)
R&D Organizations & Firms with R&D Units	• ***New, internal R&D projects*** stimulated by Center research • ***Accelerated / re-directed R&D*** internal projects underway via learning from Center research • ***R&D cost avoidance:*** Internal projects that would have been done if not for Center projects • ***Avoided R&D projects*** that would have been done if not for learning from Center research • ***Commercialization:*** New product designs / services selected for commercial development.
Manufacturing & Service Organizations	• ***Process improvements*** stimulated by Center research: Improved fabrication methods, increased speed, energy efficiency, material usage, measurement, evaluation, testing... • ***Product / service improvements*** stimulated by or based on Center research: Revised product designs, user instructions & warnings, treatment protocols... • ***Evidence-based measurement & testing protocols*** for products / services • ***Improved safety & liability forecasts*** based on evidence from Center research • ***Improved sales*** of products / services based on learning from Center research • ***Expanded staff / new jobs*** to meet added demand for improved products / services • ***Improved marketing programs*** drawing on Center research findings
Government Organizations & Agencies	• ***Public safety policies & regulations*** relevant to Center research, e.g., auto crash tolerance • ***Standards for product safety / service quality*** drawing on Center research evidence • ***Uniform testing methods / standards*** including measurement standards, data quality... • ***Dissemination of scientific knowledge*** in reports, summaries, data-bases... • ***Public information policy*** Record-keeping requirements, access / privacy standards,...

For the CChIPS government member, applicable, potential stakeholder outcomes include 9 in the first category (all but intellectual property); all 5 in the last category (specific to government organizations); and perhaps few other outcomes on this list. Similarly, members with no internal R&D operations had fewer potentially beneficial R&D-related outcomes from their CChIPS memberships.

One CChIPs non-profit member, a consumer product testing organization, benefited from the internal discussion forum provided at CChIPS by its assembly of government, industry, and university scientists. CChIPS scientists shared interests and expertise related to consumer product testing, and eventually produced an outcome of interest to the members – an informal proposal for a product testing protocol developed from joint insight and guidance. This guidance came indirectly through the Center, from a voluntary collaboration by an *ad hoc,* inter-institutional group of CChIPS-affiliated members and scientists. The interaction represented a form of industry advice perhaps uniquely available through an industry-university-government research consortium in which the members have a shared commitment to a social value – in this case, children's safety.

A full analysis of industry stakeholder outcomes would draw on information from all stakeholders, if they chose to disclose it for a public case study, and would encompass a wider range of outcomes, including short-term outcomes for external constituencies and longer-term impacts. Instead we have limited information mainly about R&D-related outcomes. Available data were collected under an agreement of confidentiality. The limited information suggests that each stakeholder sees benefits from a particular sub-set of potential R&D-related outcomes of Center membership: a profile of outcomes important to the stakeholder organization.

In an I/UCRC with a dual mission of scientific research plus action toward broad, socially valued impact, members' investment in the Center may reflect consideration of outcomes related to the action component of the mission. These involve external constituencies and beneficiary groups.

Outcomes for CChIPS External Constituencies & Beneficiary Groups

Besides universities and other research institutions with which CChIPS collaborates in scientific partnerships, the Center actively engages with members of two categories of external constituencies for professional and public outreach: 1) industry, professional, and scientific associations involved with studying, preventing, and/or treating children's injuries; and 2) targeted beneficiary groups, such as parents of young children, teen drivers, and care-takers of injured children. Table 4 lists a few, potential short-term outcomes for each of the two kinds of external groups.

Table 4. Potential Short-term Outcomes for Two Types of CChIPS External Constituencies

External Groups	Potential Outcomes of CChIPS Research Products & Other Outputs
Industry, Professional & Scientific Associations	• ***Technical knowledge transfer****:* Access to CChIPS scientific protocols & findings from CChIPS websites, presentations, articles, etc. for dissemination via association ,channels. • ***Professional & scientific exchange*** with CChIPS scientists & students at conferences related to children's injury prevention & treatment • ***Networking****:* Scientific, government & industry contacts & relationships via CChIPS forums, conferences, direct contacts & relationships • ***Conference hosting*** by CChIPS for professional / scientific / industry associations (e.g., ACIP 2011, 2012, 2013,...) • ***Collaborative projects*** with CChIPS & industry scientists & partner organizations • ***Technical knowledge transformation*** from research findings to applications, such as treatment procedures, product designs, risk forecasts, user instructions & cautions, etc. • ***Practical knowledge dissemination / education:*** Distribution of consumer guidelines, product information, healthcare treatment protocols, risk forecasts, consumer reports, etc.
Beneficiary Groups Parents, children, teen drivers...	• ***Injury risk knowledge:*** From CChIPS research, risks & forecasts from unsafe practices... • ***Preventive practices, knowledge for consumers*** Booster seat usage, seatbelts, etc. • ***Injury care knowledge:*** Evidence-based practices disseminated as consumer information • ***Teen driving risk avoidance*** Consumer information on risks & preventive actions • ***Consumer products with improved safety features*** incorporating evidence-based design guidelines applying Center research findings.

Short-term outcomes of CChIPS products and other outputs listed in Table 4 generally represent or facilitate knowledge transactions or transformations (Ponomariov & Boardman, 2013) and applications. All have an explicit or implicit goal of beneficial impact on children's safety, which can occur via multiple

paths. For example, CChIPS scientists presented research at a conference on risks of hyperthermia for children left in parked automobiles, later available in a report via Internet ([Authors,] 2012), which was eventually covered in national news media. CChIPS also posted warnings to parents on its public website about child and adolescent injury prevention. A possible impact – reduction of children's injuries and fatalities from hyperthermia or heat stroke due to being left in parked cars – may contribute incrementally to a broader, national impact on child injury prevention.

CChIPS' outreach strategy for achieving impact on child injury prevention calls for dissemination of research findings and translations as practical guidance through multiple, complementary, overlapping outputs. Of note, the IAB approved a portion of their budget to support these efforts. Some of these outputs are intended exclusively for CChIPS members; others are tailored for industry, professional, and scientific associations, and targeted, external beneficiary groups.

CChIPS Innovative Outputs for Members & External Groups Potentially Adaptable in Other CRCs

An open systems / logic model analysis might seek to link specific Center outputs with particular outcomes. However, recent research on CRC members' R&D-related benefits found ratings of usefulness of Center reports, webpage, annual meetings, and interactions with Center scientists all inter-correlated, and correlated with reported value of outcomes for member organizations (Ponomariov & Boardman, 2013). These results, like our analysis of CChIPS members' R&D-related outcomes (Table 3), suggest that CChIPS members may see beneficial outcomes reflecting a portfolio of Center products valuable for an organization-specific profile of outcomes – possibly including outcomes to external groups as well.

Whether relationships of Center outputs and outcomes are best described as discrete output-to-outcome links or composite portfolio-of-outputs to profiles-of-outcomes links remains a question for CRC research. Either is compatible with the CChIPS strategy of multiple, tailored, complementary, overlapping, and innovative outputs designed to maximize members' R&D outcomes and children's safety outcomes. However, the key to the success of logic models is that the links have meaning: a logic model that simply include lists of unrelated outputs and outcomes will prove less useful than those with proven associations.

CChIPS' outputs consist of research products and interactive events consistent with its mission and strategy, listed in Table 5 (next page). The table gives examples of CChIPS outputs to member organizations, as benefits of membership, and outputs to external groups (also available to members).

One of CChIPS' innovative products for members adaptable in other CRCs is its external investigator program and associated project management and mentoring, which have enabled the Center to host cooperative projects with external scientists at Ohio State University and Wake Forest University. Project management and mentoring procedures developed by Center leaders and IAB (board of member

representatives) include cooperatively soliciting letters of intent (LOIs) to submit proposals, reviewing LOIs, requesting proposals from selected scientists, selecting proposals for presentation at semi-annual meetings, and cooperatively reviewing and selecting proposals for funding. Once funded, a project has one or more Board member mentors (usually several) who hold regular progress teleconferences with the science teams to review the projects. Interactive management of research projects by the member representatives (incorporating elements seen in other NSF I/UCRCS) has apparently made CChIPS research projects highly cooperative, and seems to keep members thoroughly engaged.

Table 5. Examples of CChIPS Outputs for Members and External Groups

CChIPS Products & Events for Members	CChIPS Products & Events for External Groups
• ***Members-only, secure website*** for Center-private research materials & reports • ***External investigator program*** for Center-funded scientific projects by scientists at other institutions • ***Research proposals*** for CChIPS projects from Center science teams and external investigators • ***Research reports:*** Scientific background, detailed methods, early results, testing & measurement development successes & failures; testing protocols • ***Datasets / databases*** from Center research projects • ***Research presentations:*** Detailed methods, early results, research protocols, case information, images • ***Semi-annual IAB meeting:*** Cooperative review of research proposals, current projects, funding • ***Workshops*** for members and invited guests • ***Networking receptions*** at IAB meetings with students, scientists, invited speakers... • ***Research project teleconferences*** for project mentors (any IAB member who asks), scientists • ***Letters of intent*** from researchers to present proposals for IAB review • ***Forum for discussion*** by government/ industry / university scientists of product testing protocols	• ***Public research website*** describing CChIPS findings • ***Practical science-based guidance*** via public websites for parents, care-takers of injured children, teen drivers. • ***Research publications:*** Journal articles, books... • ***Research presentations*** at national & international scientific / professional conferences • ***Public reports for consumers*** e.g., national, printed report on teen driving safety • ***Workshops*** for healthcare practitioners and other professionals interested in children's safety • ***Practice bulletins*** for healthcare professionals • ***Hosted conferences*** notably ACIP 2011, 2012 & 2013 • ***Press releases*** of CChIPS research, applications • ***Media articles*** describing CChIPS findings, for example on traumatic brain injuries to children in safety seats • ***Consumer bulletins*** Instructions to parents for using child car seats, about teen driving risks, etc. • ***Social media postings***: Twitter, Linked-in group. • ***Congressional testimony*** Flaura Winston, 2011 invited witness on traumatic brain injury in children • ***Innovative information / communication technology*** Tele-center for remote collaborative injury case review. • ***Evidence-based engineering guidelines*** for product designs with improved safety / reduced risk of injury.

Another innovative, interactive resource that CChIPS offers its members – an internal discussion forum of industry, university, and government scientists with shared expertise and interest in children's safety equipment – may also be adaptable at other CRCs, perhaps not easily. Development of this kind of resource may depend on having a critical mass of member organizations sharing a particular specialty.

An example of an innovative output of CChIPS partnerships for primary beneficiary groups – teen drivers and their parents – is guidance based on new, scientific findings developed in collaboration with a CChIPS member presented in a simple, engaging, educational format via CChIPS' host institution's website on teen driver safety (http://www.chop.edu/youngdrivers). Data from 2013 show that this website has more than 24,000 visits per month. Other CRCs with missions including public outreach and impact

may also offer science-based guidance via public websites, though achieving such high usage rates could prove challenging.

Another example of a CChIPS innovative, interactive products came out of a CChIPS research project with another NSF I/UCRC, the Center for Autonomic Computing: the tele-center for remote, collaborative multi-media review of children's injuries in motor vehicle crashes, and a later adaptation to child fatality review, with real-time exchange of written files and visual images and archiving for post-review access and follow-up. Other CRCs might develop and adapt similar technology, with enough time and resources.

In conclusion, our case study of CChIPS and analysis of stakeholder outcomes and impacts suggests that this industry-university-government cooperative research center, with its dual mission of science plus value-oriented action, has important commonalities with – and differences from – a technology-focused I/UCRC. The key commonality, a need to assure sufficient, beneficial, R&D-related outcomes to motivate members to renew, enables sustainability. The key difference, a public outreach and action mission, may contribute to greater industry member retention, engagement, and cohesion – and extends the Center's focus to external constituencies, greatly expands the desired, short-term outcomes, longer-term impacts, and Center outputs required to foster them, and increases prospective impact on children's injury prevention.

References

[Authors] (2012). *Reducing the potential for heat stroke to children in parked motor vehicles: Evaluation of reminder technology.* Washington DC: National Highway Traffic Safety Administration. http://www.nhtsa.gov/DOT/NHTSA/NVS/811632.pdf

Bhide, A. (2000). *The origin and evolution of new businesses.* New York, NY: Oxford University Press.

Boardman, C. & Gray, D. (2010). The new science and engineering management: Cooperative research centers as government policies, industry strategies and organizations. *Journal of Technology Transfer, 35*, 445-459.

Cummings T. G. & Huse, E. F. (1989). *Organization development and change, 4th Ed.* St. Paul, MN: West.

Daft, R. L. (2007). *Organization theory and design, 9th ed.* Mason, OH: South-Western Cengage Learning.

Etzkowitz, H. (2008) *Triple helix innovation: Industry, university and government in action.* London: Routledge.

Feller, I., Chubin, D., Derrick, E. & Pallavi, P. (2013). The challenges of evaluating multipurpose cooperative research centers. In Boardman, C., Gray, D.O. & Rivers, D. (Eds.), *Cooperative research centers and technical innovation* (pp. 219-246?). New York, NY: Springer.

Gray, D. O. (2000) Government-sponsored industry-university cooperative research: An analysis of cooperative research center evaluation approaches. *Research Evaluation, 9*(1), 56-67.

Gray, D. O. (2008). Making team science better: Applying improvement-oriented evaluation principles to the evaluation of cooperative research centers. *New Directions for Evaluation, 118, 73-87.*

Gray, D. O., Boardman, C. & Rivers, D. (2013). The new science and engineering management: Cooperative research centers as intermediary organizations for government policies and industry strategies. In C. Boardman, D. O. Gray & D. Rivers (Eds.), *Cooperative research centers and technical innovation* (pp. 3-33). New York, NY: Springer.

Gray, D. O., DeYoung, S. E., Leonchuk, O., & McGowen, L. C. (2012). *NSF Industry / University Cooperative Research Centers - 2010-2011 Process outcome survey results: Descriptive statistics compiled from industry and faculty surveys.* Raleigh, NC: North Carolina State University.

Gray, D. O., DeYoung, S. E., & McGowen, L. C. (2013). *NSF Industry / University Cooperative Research Centers - Final report: 2011-12 Structural information.* Raleigh, NC: North Carolina State University.

Gray, D. O., & McGowen, L. C. (2008). *NSF Industry / University Cooperative Research Centers - Final report: 2006-07 Structural information.* Raleigh, NC: North Carolina State University.

Gray, D. O., Steenhuis, H. J. (2003). Quantifying the benefits of participating in an industry university research center: An examination of research cost avoidance. *Scientometrics, 58*(3), 281-300.

[Authors] (2010). Multi-level evaluation of cooperative research centers: Bridging between the triple helix and the science of team science. *Industry & Higher Education 24*, 211-217.

[Authors] (2011). When triple helix unravels: A multi-case analysis of failures in industry-university cooperative research centers. *Industry & Higher Education*, 25(5), 333-345. doi:10.5367/ihe.2011.0057

[Authors] (2012). *Center sustainability and survival: Case studies of fidelity, reinvention and leadership of industry/university cooperative research centers: final report.* Contract #EEC-0631414, Industry-University Cooperative Research Center Program, National Science Foundation, Arlington, VA, Sept., 2012.

Gray, D. O. & Walters, S. G. (1998). Expanding and diversifying the center resource base. In D.O. Gray & S. G. Walters (Eds.), *Managing the industry-university cooperative research center: A guide for directors and other stakeholders* (pp. 263-304). Columbus, OH: Battelle Press.

Jones, G. (2013). *Organizational theory, design, and change, 7th ed.* Upper Saddle River, NJ: Pearson Education, Inc. / Prentice Hall. ISBN-13: 978-0-13-272994-9.

Katz, D. & Kahn, R. L .(1966). *The social psychology of organizations.* New York, NY: Wiley.

McGowen L. (2010). *Predictors of cooperative research center post-graduation success.* Unpublished Master's Thesis. Raleigh, NC: North Carolina State University.

McLaughlin, J. A., & Jordan, G. B. (2010). Using logic models. In J. S. Wholey, H. P. Hatry & K. E. Newcomer (Eds.), *Handbook of practical program evaluation* (pp. 55-80). New York, NY: Wiley.

Ponomariov, B., & Boardman, C. (2013). Does industry benefit from cooperative research centers more than other stakeholders? In n C. Boardman, D. O. Gray & D. Rivers (Eds.), *Cooperative research centers and technical innovation* (pp. 59-75). New York, NY: Springer.

Roessner, D., Manrique, L., & Park, J. (2013). Estimating the regional and national economic impact of engineering-focused cooperative research centers. In C. Boardman, D. O. Gray & D. Rivers (Eds.), *Cooperative research centers and technical innovation* (pp. 247-273?). New York, NY: Springer.

Ruegg, R. & Feller, I. (2003). *A toolkit for evaluating public R&D investment: Models, methods and findings from ATP's first decade* (NIST CGR 03-857). Washington D.C.: U.S. Dept. of Commerce.

"Traffic Safety Facts: 2011 Data" (2013). Report #DOT HS 811 767. Washington D.C.: U.S. Dept. of Transportation. http://www-nrd.nhtsa.dot.gov/Pubs/811767.pdf

Scott, C. & Graube, M. S. (2012). *Industry-nominated technology breakthroughs of NSF Industry / University Cooperative Research Centers 2012*. Arlington, VA: National Science Foundation.

Yin, R. (2002). *Case study research: Design and methods*. Thousand Oaks, CA: Sage.

[Authors] (2012). Telecenter for secure, remote, collaborative child fatality review. *Injury Prevention*, *18*(6), 399-404.

[word counts: abstract, 228; text, 4,849; tables, 1,179; references, 819]