CENTER FOR CELLUAR CONSTRUCTION

PI: Wallace Marshall

STRATEGIC PLAN for Renewal Phase, years 6-10

VISION:

The vision of the Center for Cellular Construction is to develop an engineering discipline that will allow us to design and build cells and tissue with specific and dynamic three-dimensional structures. These structures will serve as living factories and building blocks for better and more sustainable products, materials, and devices to benefit humankind. Our long-term goal is to contribute to the development of Cellular Engineering as an emerging engineering discipline in which the engineering medium is the structure of a living cell.

It will be necessary to educate and train a new generation of highly diverse scientists and engineers who will bring a range of different perspectives and backgrounds together under the umbrella of “cellular engineering” in order to tackle this interdisciplinary goal.

During the first funding period (Phase 1), the CCC has established collaboration as the central mechanism for accelerating research progress, and has leveraged these collaborations to make major strides in learning how to manipulate and probe cell structure and function. Our progress to date has led us in several unexpected directions, most notably the pervasive role of machine learning as a core tool. During the next funding period (Phase 2), we will focus on integrating modeling and machine learning approaches for cell design with molecular methods for re-engineering cellular pathways and for probing cell state. As these approaches become increasingly standardized within the center, we will work to expand our footprint in academia and industry. Our educational program will build on approaches that we have developed during the first project period to produce a carefully documented program that will transition to independence over the next five years. In the context of knowledge transfer, we have designed a pipeline to take ideas from the lab to the real world by harnessing existing programs and providing support at key stages of translating ideas to startups, for which current support mechanisms do not exist.

RESEARCH: Specific Goals and Performance Indicators

RESEARCH Optimal Outcome 1: CellProbe: Tools for probing and measuring cell state and structure

Standardized tools exist to measure or modify any aspect of cell structure or mechanics, and to link them to molecular state.

TARGETS/ MILESTONES	ACTIVITIES / ACTIONS	PROGRESS
Objective 1.1: Build and integrate tools to perturb the morphological, and molecular state of cells and tissues. Year 6-10 Contact: Orion Weiner	1. Molecular perturbations that can be controlled with high temporal and spatial precision using optogenetics. 2. Molecular tools are integrated with predictive software developed in CellCAD	- optogenetic targeting of yeast cell division machinery is now in routine use by CCC labs for increasing cell size to test effect of enlarged organelles
Objective 1.2: Build tools to measure cell state and structure Year 6-10 Contact: Sarah Capponi	1. Improve the acquisition and analysis of high resolution, isotropic, *3D images* of cells and tissues. 2. Improve denoising, segmentation, and quantitative analysis of large high-throughput 3D data sets a. implement a robust pipeline for segmenting 3D confocal time-series images that involves machine-learning based automated image denoising and human-in-the-loop machine learning 3. Use MULTIseq platform to map the distribution of dynamical morphological behavior of the cells back to the specific epigenetic or transcriptional program that drives it.	- 3D image analysis for yeast vacuole size based on machine learning is now in routine use for identifying mutants that alter organelle size.

Objective 1.3: Generate large datasets linking perturbations to the molecular and morphological state of cells. Year 6-8 Contact: Jennifer Fung	1. Work with specific cellular chassis (e.g. cell lines or yeast strains expressing multiple organelle markers), we will begin with libraries (knockout or promoter swap libraries for yeast, CRISPRi and CRISPRa libraries for mammalian cells) and grow single clones in multiwell plates. 2. Perform live imaging on plates using the InCell6000 and use machine learning pipelines to cluster single cells and conditions according to their morphological dynamics.	- a dataset of yeast mutant knockout strains has been collected on the InCell platform and used to train machine learning algorithms to detect organelles
Objective 1.4: Universal solutions for cell and tissue structure analysis Year 6-9 Contact: Mark Chan	*1.* Focus group to evaluate shared image analysis challenges across center projects *[year 6]* 2. Evaluate existing image analysis tools for suitability in solving the types of structural analysis problems faced in cellular engineering *[year 6]* *3.* Compile best practices, new programs, bundles, data standards & transfer protocols so that each cellular structure has an available solution *[Year 7-10]*	- focus group discussions were held in quarterly meetings this past year
Objective 1.5: Put cells into a closed loop with optogenetics and AI to allow computers to learn the rules of cell biology Year 6-10 Contact: Orion Weiner	1. Computer control of cell behavior using optogenetics 2. AI that monitors cell shape and movement and learns what control signals to apply to achieve a desired behavior via reinforcement learning 3. Unpacking the AI to discover principles of cell function	- a closed-loop controller for cell migration using cell tracking and optogenetic control of cell movement has now been implemented.
Develop tools to measure cytoplasm viscosity and dynamics Year 6-8 Contact: Ray Esquerra Sophie Dumont	Develop polarization spectroscopic tools to measure microviscosity; implement tools in cells and specific parts of cells	

Ecosystem of high quality inexpensive lensed and lensless digital devices to detect and measure features of aquatic microorganisms. Year 6-8 Contact: Tom Zimmerman	Development of portable lensless devices for laboratory use. Development of lensed high-throughput devices for laboratory use. Development of lensless portable devices for field use. Deployment of portable devices for environmental monitoring.	- a number of lensless portable microscopes have now been developed in conjunction with the Optical Engineering for Biologists course
Tools to mechanically probe and describe cellular structures (e.g. mapping load-bearing connections) Year 6-10 Contact: Sophie Dumont	Develop microneedle manipulation to deform (and displace) intra-cellular structures Biosensors to report on forces in cells and tissues Microfluidic tools for cell surgery [Sindy Tang]	- calibrated microneedles have been tested and are now being deployed to measure forces inside the mitotic spindle - variety of surgical tools have been expanded to include new fabricated blades with sharper edges, arrays of blades, and fluid-based cell splitters.

RESEARCH Optimal Outcome 2: Living Bioreactor: Engineering cell structure to optimize cell function

Engineering of cellular structure becomes a widely accepted standard approach for enabling academic and industrial processes and applications.

TARGETS/ MILESTONES	ACTIVITIES / ACTIONS	PROGRESS
Objective 2.1: Engineering organelle structure Year 6-10 Contact: John Dueber	1. Engineer the peroxisome as a reactor for handling toxic biochemical reactions 2. Molecular tools to reprogram vacuole size without altering cell growth.	- mutants have been identified that increase vacuole size, and these have been shown to increase vacuole capacity for containing toxic enzymes
Objective 2.2: Engineering cell structure to improve recovery and harvesting of synthetic products Year 6-7 Contact: Orion Weiner	1. Develop an industrial yeast platform that will allow rapid induction of cell lysis using inexpensive input signals (several degrees of temperature or light). 2. Tune organelle size to store/release product to cytoplasm or cell exterior (Chan, *Year 6-7*) 3. Control cell flocculation to be triggered by product accumulation	- we are continuing to explore the properties of the budding inhibition system for yeast cell lysis
Objective 2.3: Optimize cell function by engineering organelle and cell structure Year 6-10 Contact: John Dueber	Engineer peroxisomes to enable compartmentalization of toxic enzymes while maintaining the ability to perform metabolism, and then test how alteration of peroxisome surface or volume affects biochemical output.	- we have successfully demonstrated compartmentalization of toxic enzymes in the peroxisome, and further we have now shown that increased peroxisome size leads to increased enzyme activity and higher overall output of the BIA synthesis pathway
Objective 2.4 Establish a standardized assay and prototype a platform technology to accelerate design-build-test cycle by interrogating 1000's cells structures and outputs. Years 6-10 Contact: Sindy Tang	1. Develop a yeast incubator compatible with chemical testing. Specifically, the device will allow the immobilization of yeast to provide access to introduced chemical moiety as well as having the ability to read off cellular changes. 2. Select device materials compatible with reagents/chemicals to be used 3. Design geometry, work flow compatible with high throughput screening	

Objective 2.5 Engineer synthetic pathways involving multiple organelles Year 9-10 Contact: John Dueber	1. Measure and describe structural interactions among organelles 2. Engineer pathways to deliver molecules between organelles (ex. Peroxisome → Vacuole via autophagy	- we have developed an image analysis pipeline for soft x ray tomography data to allow us to measure and quantify organelle organelle interactions in yeast cells
Objective 2.6 Synthetic approach to engineering organelle interactions Year: 6-8 Contact: Mary Mirvis	1. Partition organelles individually into vesicles, either by purification/encapsulation or by cell fragmentation/sorting [*year 6-7*] 2. Develop methods to recombine organelles by vesicle fusion [*year 7*] 3. Systematic evaluation of organelle combinations [*year 8*]	- this work is still in the planning stage. A concrete planning step was the CCC symposium on synthetic organelle interactions held this past year as a way to learn the state of the art and gain knowledge of which organelles to test

RESEARCH Optimal Outcome 3: Cellular Legos: Self-organizing multicellular structures

It is possible to direct the self-organization of multicellular structures that have properties or capabilities that single cells do not.

TARGETS/ MILESTONES	**ACTIVITIES / ACTIONS**	**PROGRESS**
Objective 3.1: Reveal new principles of multicellular self-organization and information flow by analyzing living systems using the principles and tools of engineering. Year: 6-10 Contact: Manu Prakash	1. Investigate several novel mechanisms of self-organization using a quantitative, engineering approach while simultaneously attempting to reconstitute these systems *in vitro*. 2. Understand how Calcium signaling (and other paracrine factors) among a population of coupled cells can lead to coordinate changes in the physical properties of a cell population	- this past year we have published several preprints describing cell-cell coordination by hydrodynamic signaling
Objective 3.2: Engineering artificial ECM and cell-ECM interactions Ongoing Contact: Dan Fletcher	1. Build orthogonal ECM interaction by combining chimeric receptors with functionalized polymers 2. Engineer interaction of nonliving particles with cells, engineered biomineralization of artificial ECM 3. Use synthetic approach to learn what properties of a molecule determine adhesivity 4. Engineer cells to direct traction toward specific cellular interfaces by engineering the extracellular domains of integrins with single chain antibodies directed to specific chemical species.	
Objective 3.3: Engineer self-organization and information flow to build new multicellular structures and enable new applications. Year 6-7 Contact: Zev Gartner, Wendell Lim	1. Program immune cells to partition into tissue types that they normally would avoid by using chimeric adhesion receptors (*see objective 3.2*) to manipulate their interfacial energies. 2. Long term: Engineer more reproducible *in vitro* tissues for basic	- molecular dynamics and deep learning tools have been applied to predicting CAR receptor interactions

	science research and industrial applications	
Objective 3.4: Cell generator – artificial organs that produce cells of specific types Year: 8-10 Contact: Jennifer Fung	1. Patterning stem cells and support cells using 3D self-organization to produce a robust cell production system 2. Evolutionary algorithm for designing the cell generator 3. Engineered niche to preserve cells in a healthy state until ready for use. 4. Learn the rules of organ and tissue organization for cell-producing organs by attempting to build them	- CCC personnel trained in culturing testes from male mice as a first step towards a germ cell generator

RESEARCH Optimal Outcome 4: CellCAD: A modeling and design framework for cell and tissue structure

Computational tools can reliably predict the molecular perturbations necessary to produce cells of a desired organelle-scale structure

(*Integrate information from all other themes to generate predictive models and design tools that will enable our long-term goal of building cell and tissue structures to meet the demands of specific applications.)*

TARGETS/ MILESTONES	**ACTIVITIES / ACTIONS**	**PROGRESS**
Objective 4.1 Implement a model-driven approach for CellCAD Year 6-7 Contact: Wallace Marshall	*1.* Develop a model-driven CellCAD system in which mathematical models are used as design tools *[year 6-7]* *2.* Develop methods for implementing design choices in actual cells. [*year 8-10]*	- we have developed a scheme for organelle dynamics models, and applied it to rapid development of a model for peroxisome size control
Objective 4.2 Implement a data-driven approach for CellCAD. Train machine learning algorithms to recognize non-linear correlations between molecular state and physical structure that can be exploited for design Year: 6 Contact: Simone Bianco	1. Apply machine learning and data analytic methods to large datasets in which the ensemble of organelle, cell, or tissue morphology have been measured under many different molecular perturbations. 2. Train neural networks trained using empirical data to predict molecular changes that can be combined to achieve a particular design goal. Use large data sets generated by the CellProbe and deployed in the Living Bioreactor and Cell Legos themes.	- neural networks have been trained to discriminate single and double mutants based on image data for mouse embryonic fibroblasts
Objective 4.3 Conceive and execute a design framework for programming cell and tissue structure. Year 6 Contact: Shawn Douglas	1. Develop a way to specify the desired structure of a cell, in order to integrate the design tools into a fully usable CAD tool 2. Build visual tools such as employed in parametric design, whereby the user will adjust organelle size and shape parameters using interactive sliders, with graphical renderings of consistent cell structures generated on the fly.	- we have explored a highly simplified model of organelle dynamics to ask about stability and uniqueness of solutions

Objective 4.4 CAD software for tissue self-organization Year 6-10 Contact: Shawn Douglas	1. Computational modeling of cell-cell interactions with tunable parameters 2. Parametric design tools the use the computational model to predict how interactions should be tuned to achieve a desired self-organized tissue architecture	- a parametric design and visualization program has been implemented for self-organization of multicellular structures

EDUCATION- Specific Goals and Performance Indicators

EDUCATION Optimal Outcome 1: **Educators view the framework for Cellular Engineering Education as a living document, continuing to update and refine it as the field of cellular engineering develops**		
TARGETS / MILESTONES	**ACTIVITIES / ACTIONS**	**PROGRESS**
Revisions to Framework for Cellular Engineering Education Ongoing Contact: Katherine Nielsen	1. Continue conversations with Center Faculty and industry partners on the knowledge, skills, and habits of mind needed to be successful in Cellular Engineering. 2. Continually revise and improve framework based on these conversations. 3. Given emergence of computational skills including image analysis and the application of machine learning in the work of the Center, additional work will be done to articulate how to promote skill development in this area among Center trainees.	- we continue to discuss these concepts with our external advisory committee

EDUCATION OPTIMAL OUTCOME 2: **The Center has developed an innovative cross-disciplinary training program for trainees at all levels across the center, including undergraduate, graduate students, and postdoctoral fellows. In years 6-9, courses will continue to be developed and refined, and we will work towards sustainability of Center courses.**		
TARGETS/ MILESTONES	**ACTIVITIES / ACTIONS**	**PROGRESS**
Undergraduate		
Continued integration of key cellular engineering concepts into core undergraduate courses in biology and chemistry. Ongoing Contact: Ray Esquerra	1. Ongoing review of undergraduate course syllabi with attention to where and how cellular engineering concepts and habits of mind can be integrated into undergraduate coursework at SFSU	- the cellular engineering framework has been consistenly implemented in the CCC summer course, the CE workshop, and in the Optical Engineering for Biologists course.
Strengthen partnerships between the SFSU Biology department and programs at SFSU that foster computational skills such as PINC and SCIP, with an eye towards sustainability. Years 6-9 Contact: Ray Esquerra	1. Work with SCIP leaders annually to ensure that summer immersion includes computing skills relevant to CCC Summer Course thereby providing core foundational knowledge to prepare students for success in Summer Course. 2. Continue to collaborate with PINC leadership – planning PINC capstone projects and mentoring students.	- The CCC summer course again coordinated with SCIP to have an image analysis module for undergradaute biology students
Create new major/concentration in Cellular Engineering Long-term goal - Years 8+ Contact: Ray Esquerra	1. Identify whether this is more appropriate as a major or concentration. 2. Submit proposal/course of study for approval.	
Eighty percent of undergraduate students trained in center labs go on to further STEM training	1. CCC faculty will continue to provide robust laboratory research experiences for SFSU undergrads, as well as interdisciplinary educational experiences that prepare the students to be	- we continue to exceed this goal, see Education section of annual report

Year 6-10 Contact: Frank Bayliss	competitive candidates to graduate programs. 2. Undergraduates take part in center meetings and become part of the CCC scientific community. 3. Center leadership will continue to conduct longitudinal tracking on CCC undergrads to document their educational and professional achievements.	
Graduate		
Develop and assess interdisciplinary graduate courses. Ongoing Contact: Jennifer Fung and Manu Prakash	Continue to pilot new courses using the minicourse framework. This framework allows us to rapidly develop and pilot new interdisciplinary courses that respond to emerging themes from Center research – helping prepare trainees for careers in Cellular Engineering.	- this year the Frugal Science course was highly attended and provided a way to disseminate ideas within the CCC for spreading cell biology as a global tool
Center-wide		
Continue to refine, document outcomes, and work towards sustainability of center-wide Summer Course. Ongoing Contacts: Diana Chu & Mark Chan	*1.* Using formative evaluation data from prior summer, engage in process of continuous refinement to enhance & improve Summer Course. *Ongoing* *2.* Formalize mechanism to solicit Course project ideas from Center members. *Years 6-7.* *3.* Document outcomes from Summer Course and submit manuscript on course structure and outcomes to CBE-LSE. *Year 7.* *4.* Phase-in opening of course to students from outside of Center *(Years 5-7)* and establishment of course as self-sustaining fee-based model *(Years 7-10).* *5.* Develop a succession plan for course leadership using a rotation model. *Years 6-8.*	- evaluations are fully integrated into the design and execution of the CCC summer course

Initiate semi-annual Techniques Workshops as a time for Center Members to build knowledge and skills of cutting-edge techniques across the Center Years: 6-10 Contact: Manu Prakash	1. Solicit ideas for workshops from Center Members. *Year 5, and at quarterly meetings thereafter.* 2. Identify appropriate graduate students, postdoctoral fellows or other researchers (both from within and external to the Center) to lead the workshops. *Ongoing, Years 6-10.* 3. Host two workshops per year. Workshop length will vary as appropriate for technique. *Ongoing Years 6-10.* 4. Post any materials developed for the workshop e.g. videos, protocols, resources lists on the Lecture Brick page (see Education Optimal Outcome 3).	
Postdoctoral Fellows		
Postdoctoral program for trainees from minoritized backgrounds Years: 6-10 Contacts: Frank Bayliss & Ray Esquerra	1. Develop postdoctoral program that will promote interdisciplinary training for students from minoritized backgrounds. Postdocs will be shared between two labs – one at UCSF, UC Berkeley, or Stanford, and the second at SFSU. Goal is to host 4 postdocs – two beginning in year 7, and two beginning in year 8. 2. In addition to research, postdoc will develop and lead courses at SFSU. 3. Apply for supplement grant to fund program in Year 6.	- two postdocs were recruited during the last year to perform research in CCC labs at SFSU

EDUCATION OPTIMAL OUTCOME 3:

Lecture Bricks: **Create a library of Cellular Engineering education modules, including content and ethics modules, skill/tool instruction, and short-term research projects, that can easily be adopted/adapted for a wide range of formats and institutions.**

TARGETS/ MILESTONES	ACTIVITIES / ACTIONS	PROGRESS
Center faculty and affiliates have developed and posted a series of *Lecture Bricks* to facilitate inclusion of Cellular Engineering & RRI content in courses and seminars both inside and outside of the Center. Years 6-9 Contact: Katherine Nielsen	*1.* Lecture Brick page added to the CCC website. *Year 6.* *2.* Introduction to Cellular Engineering slide deck developed and posted on website. *Year 6.* *3.* Course materials (slide decks, syllabus, materials lists, lecture videos, project ideas) for *Image Processing Pipeline* course posted to the Lecture Brick webpage. *Year 7.* *4.* Course materials (slide decks, lesson plans, handouts, materials lists and downloads, videos) for the *Cellular Construction Workshop* fully posted on Lecture Brick webpage. *Year 7.* *5.* Course materials (slide decks, ethics lessons, technique workshops, and project library) from the CCC Summer Course posted to Lecture Bricks webpage. *Years 7-9.* *6.* Center-wide proposal process to identify other Center courses, content and techniques amenable to Lecture Brick development. *Year 7.* *7.* Ongoing effort to build out Lecture Brick catalog as a resource for the cellular engineering education community. *Years 8-9.*	- A full set of lecture bricks have been added to the CCC web site, along with a slide deck providing an introduction to cellular engineering.

EDUCATION OPTIMAL OUTCOME 4:

All center members are prepared to act as ambassadors for the field by clearly communicating the importance of their work in a wide variety of settings, to help building awareness of the importance of cellular engineering and its potential to solve complex problems.

TARGETS/ MILESTONES	ACTIVITIES / ACTIONS	PROGRESS
Offer science communication and public engagement training for Center members Years 6-9 Contact: Jennifer Frazier	1. Assess needs, interests, and time availability of all Center members for communication training. *Year 6*. 2. Identify opportunities for providing training that aligns with assessment (such as one-hour seminars, longer workshops, individual feedback on demos or presentations). *Year 6*. 3. Deliver science communication training (likely adapting the courses being taught by Diana Chu and Jennifer Frazier). *Year 7-9*.	- this year the CCC offered a two week hands-on Science Communications minicourse at UCSF, run by Jennifer Frazier. - Jennifer Frazier will be presenting a training session on SciComm for the CCC summer course
Center trainees have opportunity to intern in informal education settings to further learn skills and strategies for effective public engagement at the Exploratorium. Years 6-9 - Contact: Kristina Yu	Exploratorium Internships: - Host one intern a year from Center labs using evidence-based communication training, practical experience, and special projects. *Years 6-9*. - Refine internship curriculum to include inclusive science communication training and social media outreach best practices. *Year 6.* - Increase participation from SFSU students through on-campus presentations and other more direct communications with SFSU. *Year 6.*	

EDUCATION Optimal Outcome 5:

Members of the *general public* understand that cells are dynamic entities that respond to their environments. They recognize potential of using cells as an engineering platform to solve a wide variety of problems.

TARGETS /MILESTONES	ACTIVITIES/ACTIONS	PROGRESS
Exploratorium creates four technology-focused exhibits that feature the tools being used and developed by the Center Year 6-9 Contact: Kristina Yu	1. Identify technologies being used in the Center that can be adapted into exhibits (such a machine learning algorithms, biosensors, modeling software, or microscopes). *Year 6.* 2. Create two exhibits for *Plants*, a major exhibition that will open in 2023. This allows Center exhibits to be leveraged as part of a major exhibition that will have heavy advertising, design, and framing. Examples include sensor-based exhibits or adapted Fletcher lab CellScopes. *Year 7.* 3. Create two additional exhibits to augment the existing *Cells to Self* or *Plants* exhibition area, provide heavy marketing and social media to launch during a special engineering related family weekend or After Dark evening program. *Years 7-9.* 4. Synthesize findings across development of Cell Engineering exhibits, write up at least one publication and present at two conferences (such as ASCB and ASTC). *Year 9-10.*	
15 public programs that highlight concepts, tools, and people of the Center, including yearly Latinx Engineering Days in Spanish Years 6-10 Contact: Kristina Yu	1. Develop database of faculty, their research, and relevant tools for program staff at Exploratorium to draw from. *Year 6.* 2. Arrange for at least 3 CCC members per year to present at existing Exploratorium programs (After Dark, Pairings, etc), of which 30% of faculty are from underrepresented groups. *Ongoing: years 6-10*	- programs are officialy in preparation with the new CCC team at Exploratorium

EDUCATION Optimal Outcome 6:

High school students **are aware of, and excited about, the potential of building things and solving problems with cells, and move on to STEM majors.** ***High school teachers*** **understand that cells are dynamic entities and are comfortable integrating big ideas of cellular engineering into their teaching.**

TARGETS /MILESTONES	ACTIVITIES/ACTIONS	PROGRESS
Cellular Construction Workshop becomes fully self-sustaining. Years 6-9 with complete self-sustainability achieved before year 10 Contact: Katherine Nielsen	1. Continue to offer the CCW, supporting ~12-15 students and 3-5 high school teachers each year. 2. Pilot models for funding of workshop not dependent on the NSF. These may include: • Leveraging support from other funding sources, • Partnerships with school districts • Tuition/fee-based models	- last year the CCW was partially funded by the San Francisco Unified school District
85% of high school students trained through program pursue STEM majors in college Ongoing Contact: Katherine Nielsen	Track high school participants through various means including: SFUSD Linkedin interface, National Student Clearinghouse, and surveys of program alumni	- we continue to exceed our target, as detailed in the Education section of the annual report
Develop collaborative proposal to understand the impact of the CCW on participating teachers and students. Years 6-9 Contact: Katherine Nielsen	*1.* Research partners at University of San Francisco and Digital Promise identified. Collaboratively developed NSF DRK-12 proposal to fund study. Grant pending. *Year 5.* 2. Data collection and analysis. *Years 6-7.* 3. Refinement of CCW using co-design framework to further increase benefit to teachers & students. *Years 7-9.* *4.* Dissemination of research findings in publications and through conferences. *Years 7-8.*	

BROADENING PARTICIPATION

BROADENING PARTICIPATION Optimal Outcome 1: **The Center for Cellular Construction is a model for creating a diverse STEM workforce that is emulated by other institutions**		
TARGETS/ MILESTONES	**ACTIVITIES / ACTIONS**	**PROGRESS**
All center participants have been trained in best practices for mentoring diverse populations and apply this training to all center activities Years 6-10 Blake Riggs	Diversity mentoring events are held at all annual retreats, during which faculty who have participated in NRMN and other formal training can educate other center members, from students to faculty, in data-informed best practices.	
Broadening participation goals are woven into all center activities including research, education, and knowledge transfer Year 6. Frank Bayliss	Implement a procedure for tracking and reporting diversity of participation, and steps taken to broaden participation, linked to all individual center activities, which will allow for identification of activity areas that might require additional work in this area.	
Partner institutions begin to emulate CCC approaches for collaboration between minority serving institutions and research-intensive institutions. Year 7. Wallace Marshall & Frank Bayliss	Establish an expanded network with select partner institutions that increases minority recruitment into our center while, at the same time, sharing knowledge with the partner institutions about ways to promote cooperation between institutions in broadening participation.	

BROADENING PARTICIPATION Optimal Outcome 2: **Advancement and retention of students, postdocs, and faculty towards STEM careers has been realized at all levels of participation, from K-12 to faculty.**		
TARGETS/ MILESTONES	**ACTIVITIES / ACTIONS**	**PROGRESS**
K-12 and informal science outreach activities of the Center have led to an increase in the number of URM students entering STEM degree programs Year 6 Katherine Nielsen	1. Longitudinal tracking of high school student education and career outcomes following participation in summer bootcamp program. 2. Assess impact of Exploratorium exposure on interest of URM student attendees in pursuing further education in STEM areas.	- tracking shows a large number of CCW participants pursuing higher education in STEM fields, details are provided in the Education section
80% of undergraduate URM students who participated in Center summer research will be admitted into STEM graduate programs Year: Ongoing Wallace Marshall & Hana El-Samad	1. Provide mentoring to all faculty and student/postdoc mentors in summer research labs on best practices for mentoring diverse students prior to the start of each summer session. 2. Track outcomes for summer undergraduate students and assess their experience during the summer research experience. 3. Center faculty will actively recruit URM undergraduate students to participate in center-affiliated summer research programs by visiting minority serving institutions and undergraduate student research conferences to spread the word about the Center as a major research effort that welcomes diversity.	- most participants either go on to graduate studies in STEM or else take research-oriented industrial jobs
90% of masters students in the Center ultimately join the STEM workforce, and of those who pursue doctoral-level training, 90% will complete their training successfully. Year 6	1. Masters students are fully integrated into center research, education, and knowledge transfer activities and treated as equal partners, preparing them to compete successfully at the next level. 2. Masters students are given the same opportunity as PhD students, to participate in	- we continue to exceed this goal, as detailed in the annual report

Frank Bayliss	internship programs with center partner companies.	
The number of Ph.D. students from under-represented groups entering graduate programs with which the Center faculty are affiliated has increased by 20% Year 7 Leads: Wallace Marshall & Frank Bayliss	1. Center faculty will volunteer to join admissions committees for graduate programs at their respective institutions, where they can encourage the careful consideration of URM candidates. Contact: Wallace Marshall 2. Center faculty will join diversity committees if such exist. If diversity committees do not exist for a given program, center faculty will volunteer to form such a committee. Contact: Wallace Marshall 3. Center faculty will actively recruit undergraduate students into the respective graduate programs by visiting undergraduate serving institutions and attending SACNAS/ABRCMS conferences Contact: Frank Bayliss 4. Identify barriers that prevent URM students from persisting through the Ph.D., at each participating institution, so that these can be reduced or eliminated. Contact: Frank Bayliss	- center faculty are on all the diversity committees for major graduate programs in related fields

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BROADENING PARTICIPATION Optimal Outcome 3: **Postdoctoral training has become a key element in promoting diversity and broadening participation.**		
TARGETS/ MILESTONES	**ACTIVITIES / ACTIONS**	**PROGRESS**
The number of postdoctoral fellows from underrepresented groups in Center labs increases by 10% relative to non-center labs Year 6 Lead: Wallace Marshall	1. URM postdoc applicants to any center lab will be invited to interview with multiple center labs to increase likelihood of being accepted into a center lab. 2. Postdocs are recruited from diverse pools of students 3. Integrate recruitment efforts with UCSF wide efforts to increase diversity. Participate in newly established Path-to-Postdoc UR postdoc recruitment program.	- the CCC continues to exceed national averages in diversity of postdocs
Develop postdoc training program specifically designed for postdoctoral fellows interested in 1) academic careers or 2) industry careers. Years 6-10 Academic: Frank Bayliss & Ray Esquerra Industry: Charles Hart & Charles Craik	For 1) provide teaching pedagogical workshops and opportunities to mentor undergraduates; provide opportunities to teach in SFSU courses and provide specialized workshops to undergraduates For 2, provide training in biotechnological business and entrepreneurship.	- the CCC-led Optical Engineering in Biology course has provided an opportunity for CCC postdocs to take part in teaching of diverse students, which helps to prepare them for an academic career
All center postdocs, regardless of their own minority status, are trained in broadening participation issues Years: all Lead: Wallace Marshall	Postdocs participate in mentorship training offered at their home institutions as well as in the CCC diversity mentorship training held during the annual retreat.	- we continue to make mentoring of diversity a key training element of each years retreat
Develop a new structured program for URM post-doctoral Fellows focused on convergence research Year: 6-10 Contact: Frank Bayliss, Ray Esquerra	1. Apply for supplement to support 4 shared postdocs over 3 years. Shared postdocs between 2 CCC labs at separate institutions to augment training and mentoring opportunities. 2. Leverage IRACDA program at UCSF to provide support to URM postdocs 3. Recruit postdocs through IRACDA and SF State	

BROADENING PARTICIPATION Optimal Outcome 4: **Infrastructure and partnerships between SFSU and other CCC institutions increase opportunities for diverse faculty to succeed in their research**		
TARGETS/ MILESTONES	**ACTIVITIES / ACTIONS**	**PROGRESS**
50% increase in presentations, publications, and grant awards by SFSU faculty after joining the Center Year 8	1) Establish at least one research collaboration between each SFSU CCC faculty and at least one other CCC faculty member. *Year 6* Frank Bayliss 2) Establish core facility access at all CCC institutions for SFSU faculty members. 3) Center faculty from research intensive institutions work to get SFSU faculty invitations to present their work at national meetings *Ongoing* Frank Bayliss & Wallace Marshall	

KNOWLEDGE TRANSFER - Specific Goals and Performance Indicators

KNOWLEDGE TRANSFER Optimal Outcome 1: **Ideas, discoveries, and inventions around cellular engineering emerging from the Center advance along the translational path to product development commercialization**		
TARGETS / MILESTONES	**ACTIVITIES / ACTIONS**	**PROGRESS**
Protection of Center-developed intellectual property to support product development and commercialization of the Center's novel discoveries and inventions. Year 6-10 Contact: Charles Craik & Simone Bianco	Continue procedures in place for the identification of novel intellectual property, and efficient system in place to generate invention disclosures and initial patent applications.	- we implemented a student internship program based on the TPP concept to help faculty devleop ideas for disclosure, while helping students learn about IP
Expansion of our footprint within the San Francisco Bay Area by the recruitment of new faculty as Center affiliates. These new faculty will receive seed funds ($25K) for one year to work on Center-related projects in their labs. After which the new faculty will continue to take part in the Center's quarterly meetings and retreats. Year 6-8 Contact: C. Craik, Wallace Marshall & Zev Gartner	We will use this mechanism to bring in at least five additional faculty, spread across center institutions.	- last year we provided seed funding for Dr. Ada Poon at Stanford, who is now an affiliate of the center

KNOWLEDGE TRANSFER Optimal Outcome 2:

The Center will leverage the Innovation & Entrepreneurship (I&E) resources available at our institutions. These include the Sutardja Center for Entrepreneurship and Technology and the Berkeley Haas Entrepreneurship programs at UC Berkeley; the Catalyst Program and QB3 at UCSF, and the Innovation and Entrepreneurship Fellows Program and Institute for Innovation at San Francisco State, and the SPARK and Center for Biodesign programs at Stanford.

TARGETS / MILESTONES	ACTIVITIES / ACTIONS	PROGRESS
Leveraging available I&E resources at Center institutions to advance Center discoveries along the translational path to commercialization. Year 6 Contact: Charles Hart	Initiate introductory meetings with the I&E at each of the Center's institutions. Create joint events bringing together Center faculty, staff, and students with the respective I&E programs' participants and stakeholders	
Center discoveries and inventions provide starting points for entrepreneurial and business creation activities at the I&E affiliate at the Center institutions. Year 7-10 Contact: C. Hart	Center discoveries becoming the basis and focus of entrepreneurial activities at the affiliated I&E programs at the Center institutions.	

KNOWLEDGE TRANSFER Optimal Outcome 3: **Create partnerships between Center programs and faculty, staff and students with existing companies and start-up companies**		
TARGETS / MILESTONES	**ACTIVITIES / ACTIONS**	**PROGRESS**
Establishment of collaborations and partnerships with existing or start-up companies to explore applying cellular engineering approaches in industrial processes or the development of new products. Year 6-10 Contact: Charles Hart w/ Charles Craik	Update the Center's "pitch deck" that any center member can use to introduce the center concept, focuses, and activities Establish dialogues with 3-5 companies per year working on cell engineering, biotechnology, synthetic biology, computational biology, fermentation processes, and materials production to explore potential collaborations, partnerships, or licensing agreements.	
Promotion of Center-internal entrepreneurship to foster new company formation or industrial partnerships Year 6-10 Contact: C. Hart	Leverage Center funds and contacts to identify opportunities for startup support through alternative RFAs, VC, existing companies, and philanthropy.	

KNOWLEDGE TRANSFER Optimal Outcome 4: **An active and broad Center Internship program that links programs and faculty with students and trainees with a goal of practical experience and exposure to Center activities and I&E endeavors.**		
TARGETS/ MILESTONES	**ACTIVITIES / ACTIONS**	**PROGRESS**
Expand the Center's internship program to include educational opportunities in Innovation and Entrepreneurship (I&E) and practical experiences in Center labs and offices. Year 7-10 Contact: C. Hart	We will create an internship program that will be integrated into the ongoing internship program coordinated by the UCSF Catalyst Program. The Catalyst Program shares the CCC's goals in promoting the advancement of academic discoveries along the translational path to product development and commercialization. The Center's internship program will expose CCC trainees to both real-world entrepreneurial activities as well as seminars and discussion groups. Topics covered will include: regulatory affairs, financing, intellectual property, business development, project management, quality systems, and incubators and accelerator programs.	- we have successfully launched this internship program, and the work of the first student team led to submission of a patent application by the Tang group on a CCC related invention
Include Innovation & Entrepreneurship (I&E) topics at Center quarterly meetings. Year: 6-10 Contact: C. Hart, C. Craik, D. Singer	Utilize Center faculty, staff, and student presenters on I&E, as well as outside invitees.	

KNOWLEDGE TRANSFER Optimal Outcome 5: **Center-trained students and fellows entering the workplace, whether in the private-, public-, or nonprofit-sectors and bring with them their Center training, knowledge and experiences.**		
TARGETS/ MILESTONES	**ACTIVITIES / ACTIONS**	**PROGRESS**
Center trainees' subsequent jobs, fellowships, or volunteer activities enriched by their time and experiences in the Center Year 3-5 Contact: D. Singer	Continue contact with former trainees of the Center with goal of contributing to their success in their new roles. Center's impact on the trainees having a positive impact on their new companies or institutions. Center will have contact with these companies to allow exploration of possible future collaborations, also providing former trainees a way to stay connected with the Center.	- CCC students and postdocs have moved into leadership positions in industry, as detailed in the annual report
Close, ongoing interactions between the Center and its former trainees will create a network. Year 9-10 Contact: D. Singer / C. Hart	Create an active Center alumni organization via focused professional social media with a goal to maintain the ties created during their student and trainee years at the Center.	

KNOWLEDGE TRANSFER Optimal Outcome 6:

A rich and robust presence on the WWW (via the Center's website) and professional social media (via the Center's Twitter and LinkedIn feeds) of Center discoveries, inventions, and product developments. Prolific publication of both primary research papers, review papers, and articles and note in the trade and lay press (e.g. op-ed pieces).

TARGETS/ MILESTONES	ACTIVITIES / ACTIONS	PROGRESS
Center website and professional social media channels (Twitter and LinkedIn) conveying center goals, ideas, and results to a broad range of stakeholders, potential collaborators, and the general public. Years all Contact: D. Singer (web site), Diana Chu (social media)	Actively maintain and update website. Regularly post or re-post news or information items emerging from the Center, or from outside the Center with relevance to Center activities and goals. Ensure the content includes scientific, technological, educational, and ethical activities and learnings from the Center.	- extensive content development for the new CCC web site during the past year
The publication of peer-reviewed scientific and technical papers in scholarly journals (primary and review papers) Year all Contact: Center Directors assess during annual reporting	Papers (both primary and review) published in peer-reviewed publications. Abstracts published of the proceeding of scientific conferences.	- as detailed in Centerwide Outputs, productivity of publications continued to be strong despite the covid pandemic
Publication of articles in trade publication and the lay press. Year all Contact: Hana El-Samad	Center-authored application notes and technology white papers. Op-ed pieces in newspapers and magazines. Scientific review articles that highlight Center concepts and themes	

Host a symposium on “Cellular Engineering” that will bring Center faculty, staff, and students together with interested researchers from around the country, with a focus not just on presenting ideas but on catalyzing new collaborations. Year : 9-10 Contact: Wallace Marshall	Symposium to take place during the last two years of the grant term.	- we already held a symposium this past year, organized by CCC postdocs, which lays the foundation for future symposia

RESPONSIBLE RESEARCH AND INNOVATION –

Ethical, Legal, Environmental, Societal and Governance Issues in Research & Innovation (ELSI)-

Specific Goals and Performance Indicators

ELSI Optimal Outcome 1: **CCC alumni in both academic and industrial cellular engineering roles are aware of the ethical implications of engineering cells and are trained in how to think about the ethical, legal, societal & governance issues and implications of their work**		
TARGETS/ MILESTONES	**ACTIVITIES / ACTIONS**	**PROGRESS**
100% of center participants have been trained in responsible conduct of research at their home institutions Year 6 and each year thereafter Contact: Frank Bayliss & Ray Esquerra	Implement a system for tracking progress of training across center institutions.	
All graduate students and postdoctoral trainees in Center labs have been trained in ethical questions related to Cellular Engineering End of Year 7 Contact: Robert McGinn	1. Develop polished materials to initiate students and faculty to the ethical implications of the discipline 2. Demonstrate that ELSI is a priority for the Center by devoting time to ELSI topics/trainings regularly at Quarterly Meetings and at each Annual Retreat	- Dr. McGinn ran a session at the last summer retreat based on the Theranos case
High school students and teachers are introduced to 1) the field of ethics broadly and 2) the role of ethics in the practice of science Year 6 (and ongoing) Contact: Katherine Nielsen	Leverage existing materials in use in SEP programs to teach ethics in the context of science to high school students & translate these materials to a cellular engineering context.	

Develop a series of CCC-related ethics modules that can be used in Center courses to elucidate key RRI principles and elicit discussion. Year all Contact: Robert McGinn & Katherine Nielsen	1. Identify ethical concerns arising from CCC research via surveys/ discussions with center members 2. Develop case studies around CCC-identified issues or related scenarios. RRI/entrepreneurship case studies will draw from beyond the Center, including news reports and SEC actions (e.g. Theranos). 3. Provide tools, resources, ways of thinking to support members tackling these topics 4. Develop modules to be used in courses, at Center Retreats and Quarterly Meetings, in lab meetings and journal clubs and disseminated to the public on the Lecture Bricks page of the CCC website.	- this past year we developed a module based on the Theranos case, which has also led to a publication
Leverage Institutional Resources and programs at other NSF STCs Ongoing Contact: Debra Singer	1. Actively partner and engage with other NSF-funded Centers to share ethics resources and approaches to strengthening RRI. 2. Connect with relevant NSF or federally funded ELSI programs engaged in studies on best practices in developing Ethical & Responsible Research conduct and which cultural and institutional contexts promote ethical STEM research and practice.	

ELSI Optimal Outcome 2: **Center exploits state of the art technology to monitor and contain potential spread of industrially relevant cellular systems**		
TARGETS/ MILESTONES	**ACTIVITIES / ACTIONS**	**PROGRESS**
Best practices for biosafety are established for center activities Year 6 Contact: Wallace Marshall	1. Consult with ethics advisory panel and institutional safety officers to determine potential laboratory hazards entailed by center engineering activities 2. Harness existing standard operating procedures and training to mitigate the specific types of risk that arise during center work.	
Genetic containment strategies are implemented for key industrially relevant microbes Year 7 Contact: Wallace Marshall	Research existing options for containment, such as engineered dependency and kill switches, and invest research resources if these prove inadequate	

ELSI Optimal Outcome 3: **Stakeholders and general public are engaged in and aware of the center's commitment to ethics and safety**		
TARGETS/ MILESTONES	**ACTIVITIES / ACTIONS**	**PROGRESS**
Center web site has a section discussing ethical implications with commentaries, readings and other resources Year 6 (and ongoing) Contact: Robert McGinn, D. Singer	1. Discuss with ethics panel to determine what aspects of center activity might generate ethical concerns among the public and stakeholders 2. Continue developing web site content that sets forth the center's approach to mitigating risk, while discussing the balance between risk and reward	- ethics material has been made available to CCC members on the web site
Ethical considerations are addressed whenever the center engages with broader audiences Year 6 (and ongoing) Contact: Jennifer Frazier	1. Speakers from the center presenting talks to the general public include a section in the talk addressing ethical concerns 2. Center publications aimed at the public and the larger engineering community address ethical issues	- ethics has been incorporated as a key point in the science communication minicourse

LEADERSHIP AND MANAGEMENT - Specific Goals and Performance Indicators

Optimal Outcome 1: **The center is an integrated community that lowers barriers for collaboration and creates new connections between participants at all levels**		
TARGETS/ MILESTONES	**ACTIVITIES / ACTIONS**	**PROGRESS**
Mechanisms exist to foster and support collaboration and interaction among center members Year all Contact: Wallace Marshall & Zev Gartner	1. Continue quarterly all-hands meetings 2. Continue annual center-wide retreat that will focus on overall progress and team integration activities 3. Establish quarterly group meetings for the main research project groups, as well as for education, broadening participation, and knowledge transfer 4. Center-wide working groups combine multiple project areas by focusing on specific highly collaborative goals that span center project areas 5. Broaden use of center-wide electronic communication platforms to facilitate collaboration	- we are gradually resuming in-person versions of these meetings, which had been held virtually for the past two years
All center members understand how their work fits in with the center and existing collaborations Year 6 Contact: Zev Gartner	1. Develop mechanism for onboarding of new center members (students and postdocs) which involves specific discussion of benefits and responsibility. 2. Director addresses benefits and responsibilities at the annual retreat each year 3. Benefits and responsibilities are specifically stated in the center's internal web site	- center overview and culture continues to be part of the introductory talks at quarterly meetings and annual retreat

Center has developed a cohort of 10- 20 collaborators outside the center involved with research, education. knowledge transfer, or broadening participation activities Year 6-8 Contact: Wallace Marshall, Zev Gartner & Charles Craik	1. Center faculty and research working groups seek outside collaborators. 2. Implement a Center Affiliate program to identify potential collaborators and involve them in center meetings and seminars.	- the center affiliate program has led to two new collaborations

LEADERSHIP AND MANAGEMENT Optimal Outcome 2:

Center decision-making is transparent and ensures that all voices are heard

TARGETS/ MILESTONES	ACTIVITIES / ACTIONS	PROGRESS
Center members are aware of the process by which decisions are reached, the status of center goals and progress, and any potential problems or hurdles the center is facing Year 6 Contact: Wallace Marshall Zev Gartner	1. Continue development of internal web site where members can go to read the center's strategic plan and updates from the leadership team 2. Reports from the leadership team at all regular meetings to keep members updated. 3. Center-wide Listserv to communicate upcoming events and decisions to all center participants	- all key documentation is now available to CCC members on the members section of the web site
All center faculty have the opportunity to provide input into the activities of the center Year 6-10 Contact: Zev Gartner	1. Implement a monthly center PI phone conference for exchanging ideas and concerns 2. Conduct a center-wide brainstorming session at each annual retreat 3. Rotate the Center Internal Advisory Committee to allow more faculty to have a voice in center planning	- monthly PI call and brainstorming sessions continue on schedule
Students are included in decision making and organization Year 7 Contact: Debra Singer	1. Student-organized events at quarterly meetings and annual retreats 2. Student representation at the PI meetings held during the quarterly meetings 3. Student /postdoc representation at strategic planning meetings	- trainees took part in the strategic planning meeting and their idea for a symposium was implemented this past year

LEADERSHIP AND MANAGEMENT Optimal Outcome 3: **Center leadership tracks progress in all goal areas and shifts resources as necessary to maintain progress**		
TARGETS/ MILESTONES	**ACTIVITIES / ACTIONS**	**PROGRESS**
Progress in research, education, broadening participation, and knowledge transfer is tracked relative to strategic goals Year 6 Contact: Debra Singer	1. Requests for status updates will be sent to all center PIs twice per year, once in the fall and once in the spring in preparation for the annual report 2. Annual re-evaluation of center progress will be performed in conjunction with preparation of the center annual report	- we have developed a questionnaire that is sent to all faculty twice per year for collecting this information
Center decision making is coordinated among the leadership and management team Year 6 Contact: Wallace Marshall	1. Weekly meetings of the Executive Committee, with financial analyst included as needed 2. Monthly long-range planning discussions between the Center Director & Co-Director	
Center planning is augmented by personnel with expertise in large center program oversight, different approaches to DEI, and in bigger picture social science and bio-ethics Year 6 Contact: Debra Singer	1. EAC includes expertise in NSF Center Program Management, different perspectives in DEI, social science and bioethics 2. EAC meetings 2 x yearly 3. Guest speakers to provoke thought	- EAC was revised for the renewal
Underperforming members are given opportunity and support to become more actively engaged Year 7 Contact: Wallace Marshall, Zev Gartner	1. Underperforming members as identified in annual reviews will meet with center leadership team to determine whether the problem is lack of interest or because of external pressures 2. In the case of lack of interest, members will have the choice to become more engaged, or to withdraw from the center	

	3. In the case of low productivity due to external pressures, center leadership team will provide mentorship and explore ways to support the member	
A strategic reserve fund allows the center to exploit new opportunities and to continue operations if funding gaps arise Lead: Exec Committee (Marshall, Gartner, Singer)	1. Strategic Reserve is available to explore new directions related to center goals 2. If funding gaps from NSF occur, strategic reserve can be used to maintain key personnel until funding resumes	- a strategic reserve has been maintained and has been used for key opportunities such as postdoc recruitment at SFSU

SUCCESSION PLANNING OPTIMAL OUTCOME: **The Center is able to continue its mission even if members of the leadership team leave the center**		
TARGETS/ MILESTONES	**ACTIVITIES / ACTIONS**	**PROGRESS**
A formal plan is in place to handle succession in the event that the current director is no longer able to act in that role Year 6 Wallace Marshall, Zev Gartner	1. The leadership team will review the existing succession plan that was developed during the first site visit	- a succession plan is in place and was used to handle the turnover of leadership personnel during the last year
All leadership team members have designated successors who are kept updated to the corresponding component of center activity Year 6 Wallace Marshall, Zev Gartner	1. The co-directors will assign a designated successor for each leadership team member, and update this individual on the nature of the responsibility involved. 2. Each leadership team member will meet with their designated successor at the time that the annual report is prepared, in order to update them on progress and challenges that might have taken place.	- the constant updating of designated successors (for examples, Drs Nielsen, Capponi, and Yu) made the transition of key personnel extremely easy this past year
A mechanism is in place to replace any center members who withdraw from the center Year 6 Wallace Marshall, Zev Gartner	1. If any center members withdraw from the center, the leadership team will evaluate possible replacements from among the cohort of Center Affiliates	- given the drawdown of funds expected in the next few years, the decision was made not to replace Hana El-Samad, who left UCSF, in order to use the funds to maintain existing programs

SUSTAINABILITY OPTIMAL OUTCOME: Successful Center Activities continue to operate after NSF funding for the CCC has ended		
TARGETS/ MILESTONES	**ACTIVITIES / ACTIONS**	**PROGRESS**
The Center leverages its NSF-supported research to seek additional sources of funding for research, education, and knowledge transfer Year 6-10 Zev Gartner	1. Center faculty prepare grants for research and other activities that extend currently funded CCC research projects in novel directions or contexts beyond the scope of current funding 2. A mechanism exists for CCC knowledge transfer activities to be supported by the UCSF Catalyst program 3. Secure funding for administrative and operating costs after sunset of NSF STC	.- CCC work has already led to extensive extramural support as detailed in Section X.
Center Education activities become self-sustaining Year 8 Rebecca Smith	1. The Summer High School Teacher/Student workshop (CCW) has a mechanism for paid access by students and teachers with the resources to do so 2. The Cellular Engineering Summer Course for undergraduate and graduate students will become a formally listed SFSU course, allowing it to be supported by student tuition after the CCC funding ends 3. Courses for undergraduates and graduate students are formal courses at SFSU and UCSF so that they will keep running after CCC funding ends	