WHEREAS, There is an emerging field in functional printing comprising printed electronics, security printing, active packaging, and additive manufacturing, projected to grow substantially in the next several decades; and

WHEREAS, Functional printing uses conventional and emerging printing techniques, many of which are already in place in the Graphic Communication Department, to produce new electronic devices, security features, and functional packaging; and

WHEREAS, The graphic communication industry stands ready to support the Master’s degree program with advanced laboratory technology to further Cal Poly’s Learn by Doing pedagogy; and

WHEREAS, The Graphic Communication Department has taught undergraduate coursework in printing and imaging for more than sixty years and can leverage that expertise in graduate education; and

WHEREAS, Cal Poly’s Graphic Communication Department is considered one of the leading institutions in the country for undergraduate education in graphic communication; and

WHEREAS, The Graphic Communication Department is proposing a Master of Science degree in Printed Electronics and Functional Imaging, comprised of online and face-to-face coursework culminating in scholarly research projects; and

WHEREAS, The College of Liberal Arts Curriculum Committee and the Academic Senate Curriculum Committee have carefully evaluated this proposal and recommend its approval; therefore be it

RESOLVED: That the Academic Senate of Cal Poly approve the proposal for the Master of Science in Printed Electronics and Functional Imaging and that the proposal be sent to the Chancellor’s Office for final approval.
Cal Poly, San Luis Obispo

Summary Statement of Proposed New Degree Program in
Printed Electronics & Functional Imaging
for CSU Academic Master Plan Projection

1. Title of proposed program:
   Master of Science in Printed Electronics and Functional Imaging

2. Reason for proposing the program:
   Functional Printing encompasses academic coursework related to several emerging graphic
   communication applications: Printed Electronics, which Das and Harrop (2011) project to grow
   from a $2.2 billion today into a $44.25 billion industry over the next decade; Active and Intelligent
   Packaging, projected by Research and Markets (2011) to grow to $23 billion per year over the next
decade; and Security Printing. The European research institute PIRA predicts the global market for
brand protection to reach a value of more than $11.4 billion by 2014 (Mc Loone, 2010). Further,
other additive manufacturing areas, including 3D printing, are gaining in popularity.

These fields involve the application of specialty inks to produce functional and optical devices
including a number of new high-tech printing applications. Active packaging focuses on printed
packaging that improves shelf life or enhances supply-chain tracking. Anti-counterfeiting is critical
for brand protection. Using both conductive and insulating inks, printed electronics and functional
imaging offer low-cost production of displays, lighting and energy harvesting devices on flexible
substrates.

The Master of Science in Printed Electronics and Functional Imaging will prepare graduates for
conceptual and practical electronic or functional applications, advanced research, and the
development of intellectual property related to the use of printing and coating technologies in these
emerging fields. This Master of Science degree integrates well with the undergraduate Graphic
Communication degree offered at Cal Poly, which largely focuses on graphic printing and imaging
technologies. The Master of Science degree engages students in critical thinking and conducting
seminal research using the department’s significant capital assets. The degree will further enhance
the department’s relationship with industry, allowing students to engage immediately with leading
industry professionals. This program will leverage the strengths of the undergraduate program
while developing increased research opportunities in the department.

This degree is offered as a self-support program under CSU Executive Order No. 1047.

3. Expected student learning outcomes and methods for assessing outcomes:

<table>
<thead>
<tr>
<th>SLO</th>
<th>Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analyze the theoretical foundations underpinning conductive materials, optical patterning, basic electronic components and circuits, and material behavior.</td>
<td>Graduate faculty will assess theoretical foundations through projects produced in GrC 530 as well as the literature reviews associated with GrC 596 using custom evaluation rubric.</td>
</tr>
<tr>
<td>Integrate graphic design, functional design, and creative applications into expressive technologies (technologies that enhance human interaction) though compelling products.</td>
<td>Graduate faculty will assess graphic and functional integration through projects produced in GrC 530 and research projects in GrC 596 using custom evaluation rubric.</td>
</tr>
<tr>
<td>Effectively present and defend scholarly research methodologies, findings, and implications in written form.</td>
<td>Graduate faculty will assess writing skills as demonstrated through the students written summative research project paper using custom evaluation rubric.</td>
</tr>
</tbody>
</table>
Evaluate and determine the suitability for printing as a production method for specific functional and novel products.

Develop specifications and tolerances for deposition technologies for various functional products.

Demonstrate knowledge related to microscale patterning and deposition including accurately measuring patterning and deposition characteristics using a variety of instruments.

Analyze multiple equipment technologies against required specifications and tolerances and determine appropriateness or equipment modifications required.

Evaluate fundamental business concepts related to starting and managing an entrepreneurial operation.

Effectively present and defend scholarly research methodologies, findings, and implications orally.

Graduate faculty will assess evaluation ability for suitability of printing through a summative paper in GrC 530 using custom evaluation rubric.

Graduate faculty will assess specifications and tolerance development through summative paper in GrC 530 using custom evaluation rubric.

Graduate faculty will assess microscale patterning and deposition through practical evaluation in GrC 530 using custom evaluation rubric.

Graduate faculty will assess equipment technology analysis through summative paper in GrC 530 using custom evaluation rubric.

Graduate faculty will assess fundamental business concepts via a business plan developed in GrC 520 using custom evaluation rubric.

Graduate faculty will assess oral communication of scholarly research during presentation in GrC 596 using custom evaluation rubric.

4. **Anticipated student demand:**

<table>
<thead>
<tr>
<th>Number of Students</th>
<th>at initiation</th>
<th>3 years after initiation</th>
<th>5 years after initiation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Majors</td>
<td>10-15</td>
<td>20-30</td>
<td>30-45</td>
</tr>
<tr>
<td>Number of Graduates (cumulative)</td>
<td>0</td>
<td>20</td>
<td>50</td>
</tr>
</tbody>
</table>

A comprehensive online survey was conducted by contacting professors from around the world who may have undergraduate students interested in this type of degree program. Additionally, GrC alumni were contacted using a variety of email lists and alumni groups. Here are some key results:

- 375 individuals completed all or most of the survey
- Of those who participated, 275 where current undergraduates and 83 had completed their bachelor’s degree.
- 235 survey respondents were likely, very likely, or planning on pursuing a graduate degree in the next five years.
- 167 survey respondents expressed interest in Cal Poly’s proposed graduate program in Printed Electronics and Functional Imaging.
- Of those, 118 individuals provided contact information and requested more information about the proposed degree program.

5. If additional resources (faculty student allocations, support staff, facilitates, equipment, etc.) will be required, please identify the resources, indicate the extent of the college’s commitment
to allocate them, and evidence that college decision-making committees were aware of the
source of resource support when they endorsed the proposal. If the college expects the
University to provide additional resources, please identify the resources and anticipated cost:
On startup, the degree program will use existing Graphic Communication Department laboratories,
equipment, and staffing. Existing faculty will teach on an overload basis through Extended
Education. As a self-support program, success may afford opportunity to add faculty to the GrC
staff in the future. As additional resources become available through strong enrollments, faculty and
equipment may be acquired. Additionally, the Graphic Communication Department has a strong
record of development by in-kind donations, grant funding, and endowments, which will be used to
strengthen the financial undergirding.

6. If the program is occupational or professional, summarize evidence of need for graduates
with this specific educational background:
At the Printed Electronics USA 2011 conference November 30-December 1 in Santa Clara, CA,
seventeen employers were asked the following questions:
1. Within the next five years, do you expect to hire employees in your company who help you
develop, improve, or scale your production system(s)?

   All survey respondents indicated they will be hiring in the next five years.

2. If yes, could you see hiring an individual with a Master's of Science degree who...
   - Generally understands deposition and patterning systems for printed electronics, smart
     packaging, and security printing.
   - Can measure, analyze, and optimize key variables in printing technologies
   - Can measure, analyze, and optimize web handling systems
   - Can measure, analyze, and optimize material/ink compositions
   - Can measure, analyze, and optimize morphologies (ink film surfaces)
   - Can measure, analyze, and optimize drying/annealing systems
   - And knows the issues related to scaling reproduction systems for commercial
     applications?

   Sixteen of seventeen (94%) indicated they could see hiring an individual with this particular
   background in the next five years.

There were more than 1200 attendees at the Printed Electronics USA 2011, an increase of 250
attendees from the previous year. Cal Poly's proximity to the Silicon Valley is critical, as many of
the companies in this space stem from conventional electronics and are looking for the opportunity
to develop new products and improve manufacturing techniques.

7. If the new program is currently a concentration or specialization, include a brief rationale for
conversion:
Printed Electronics and Functional Imaging is not currently a concentration or specialization.

8. If the new program is not commonly offered as a bachelor's or master's degree, provide
compelling rationale explaining how the proposed subject area constitutes a coherent,
integrated degree major which has potential value for students. If the new program does not
appear to conform to the CSU trustee policy calling for “broadly based programs,” provide
rationale:
The program is a natural extension of the Graphic Communication undergraduate degree. However,
it has broad appeal to students with complimentary undergraduate degrees as well, including but not
limited to: Business, Graphic Design, Physics, Chemistry, Packaging, Electrical Engineering,
Materials Engineering, and Mechanical Engineering. This degree will provide a coherent path into a
specialized application area for broader undergraduate degrees. While this degree may not technically qualify as a “broadly based program,” it is designed to touch on various applications of functional printing, including printed electronics, active packaging, security printing, 3D printing, and other functional print manufacturing. These emerging applications have broad interest and will shape society into the future.

9. Briefly describe how the new program fits with the mission and/or strategic plan for the department, college and/or university:

This degree program fits well with the Graphic Communication mission by focusing on research and discovery. The degree program leverages the equipment base along with research interests of faculty to extend the scholarship of the department and further its influence in shaping graphic communication technology. The College of Liberal Arts offers diverse, significant curricula. This program strengthens the college’s unique role in anticipating the future and defining it in light of human experience. With a focus on deployment, this degree addresses the human experience and how laboratory research can be scaled to impact the broader population. This Master’s of Science degree is focused on technology development and deployment in the context of advanced printed materials. It serves to directly meet the STEM objectives of the university as well as the college and department.

10. Attach a display of curriculum requirements:

COURSEWORK (45 Units)
MS Printed Electronics and Functional Imaging

General Characteristics
The MS in Printed Electronics and Functional Imaging is a 45 quarter-unit academic course of study preparing graduates for professions involving electronic or functional applications incorporating the use of various printing and coating technologies. The program focuses on solution-based printing and coating for novel electronics, active and intelligent packaging, and security printing. Graduates conduct research related to design, market and technology development, integration, and applications for mass-scale printing and coating technologies used in functional and novel electronics, anti-counterfeiting, and packaging.

Culminating Experience
All students are required to pass a comprehensive examination, which is normally given during the final quarter of the program.

Tuition and Fees
As a special session program through Continuing Education and University Outreach, the MS Printed Electronics and Functional Imaging program is administratively and academically completely self-supporting. As such, the program carries a separate tuition and fee schedule. Please contact the Graphic Communication Department office for the current program costs.

Admission/Acceptance Requirements
Acceptance to the program is based upon:
- Submission of an application for graduate admission via www.csumentor.edu.
- Achievement on the Graduate Record Examination (GRE).
- Two letters of recommendation.
- A Bachelor degree or diploma in a related field to graphic communication, science, or engineering from a regionally accredited institution, college or university. An undergraduate grade point average of 3.0 or 90 quarter units of the undergraduate degree. On occasion, where other credentials are exceptionally strong, a GPA of 2.5-2.99 or alternate Bachelor degree with relevant work experience may be considered for admission.
- Completion of an undergraduate or graduate statistics course with a "C" or better.
- Prerequisite experiences - completed coursework or equivalent experience to GrC courses:
  - GrC 201 - Digital Publishing Systems
  - GrC 316 - Flexographic Printing Technology
  - GrC 329 - Web Offset and Gravure Printing Technologies
  - GrC 357 - Specialty Printing Technologies
- All graduate applicants, regardless of citizenship, whose native language is not English and whose preparatory education was principally in a language other than English must demonstrate competence in English. Those who do not possess a bachelor’s degree from a postsecondary institution where English is the principal language of instruction must take either the Test of English as a Foreign Language (TOEFL) or the International English Language Testing system (IELTS) exam.
- Students may be conditionally admitted based on the successful completion of the appropriate prerequisite coursework.

Coursework (45 Units)
Core Courses (29 units)
GrC 501 - Survey of Functional Printing .................................................. 2.0
GrC 502 - Orientation to Functional Printing ................................................ 2.0
GrC 510 - Materials for Functional Printing ................................................. 4.0
GrC 512 - Printing and Coating Technologies ............................................. 4.0
GrC 514 - Imaging for Electronics & Functional Printing............................ 4.0
GrC 520 - Functional Print Product & Bus Dev ............................................. 4.0
GrC 530 - Functional Printing Workflows ................................................... 4.0
GrC 560 - Grad Res Methods in Print Elec & Func Imaging .......................... 2.0
GrC 596 - Research Proj in Printed Elec & Func Imaging ............................. 3.0
Advisor Approved Electives (16 units)
Select from the following: .......................................................................... 16.0
GrC 500 - Spec Problems in GrC for Grad Students .................................... 2.0
GrC 551 - Current Trends in Printed Electronics ........................................... 4.0
GrC 552 - Current Trends in Active Packaging ........................................... 4.0
GrC 553 - Current Trends in Sec & Anti-counterfeiting ............................... 4.0
GrC 595 - Cooperative Education Experience ............................................ 12.0
IME 427 - Design of Experiments ............................................................... 4.0
IME 457 - Advanced Electronic Manufacturing ........................................... 4.0
IME 458 - Microelectronics and Electronic Packaging ................................. 4.0
Other courses as approved by academic advisor
TOTAL ......................................................................................................... 45.0

Graduates Are Prepared To
- Analyze the theoretical foundations underpinning conductive materials, optical patterning, basic electronic components and circuits, and material behavior.
- Understand applications, trends, and market drivers for active packaging, security printing, and printed electronics.
- Integrate graphic design, functional design, and creative applications into expressive technologies and compelling products.
- Evaluate and determine the suitability for printing as a production method for specific functional and novel products.
- Develop specifications and tolerances for deposition technologies for various functional products.
- Demonstrate skills related to microscale patterning and deposition including accurately measuring patterning and deposition characteristics using a variety of instruments.
- Analyze multiple equipment technologies against required specifications and tolerances and determine appropriateness or equipment modifications required.
- Understand fundamental business concepts related to starting and managing an entrepreneurial operation.
- Conduct scholarly research in one or more disciplines in functional printing.

Structure
The 45 quarter-unit MS degree contains five online foundational courses in addition to several laboratory-based face-to-face courses that must be taken in residence at Cal Poly. Online courses may be taken in residence or prior to arriving on campus. Online courses are offered predominantly over an eight-week term on a quarterly basis.
I am pleased to approve the above-entitled Academic Senate resolution. The Associate Vice Provost for Programs and Planning is hereby directed to proceed with implementing this resolution.

Please express my appreciation to the members of the Academic Senate for their attention to this important curricular matter.