THE UNIVERSITY OF ARIZONA

New Academic Program Workflow Form

General

Proposed Name: Additive Manufacturing

Transaction Nbr: 00000000000066

Plan Type: Minor

Academic Career: Undergraduate

Degree Offered:

Do you want to offer a minor? N

Anticipated 1st Admission Term: Fall 2020

Details

Department(s):

AGSC

DEPTMNT ID	DEPARTMENT NAME	HOST
1230	Biosystems Engineering	N

ENGR

DEPTMNT ID	DEPARTMENT NAME	HOST
2302	Systems & industrial Engineering	N
2305	Aerospace & Mechanical Engineering	N
2308	Civil and Architectural Engineering and Mechanics	N
2804	Materials Science & Engineering	Y

Campus(es):

MAIN

LOCATION	DESCRIPTION
TUCSON	Tucson

Admission application terms for this plan: Spring: Y Summer: Y Fall: Y

Plan admission types:

Freshman: Y Transfer: Y Readmit: Y Graduate: N

Non Degree Certificate (UCRT only): N

Other (For Community Campus specifics): N

Plan Taxonomy: 14.3601, Manufacturing Engineering.

Program Length Type: Program Length Value: 0.00

Report as NSC Program:

SULA Special Program:

Print Option:

Diploma: Y Minor in Additive Manufacturing

Transcript: Y Minor in Additive Manufacturing

Conditions for Admission/Declaration for this Major:

N/A

Requirements for Accreditation:

N/A

Program Comparisons

University Appropriateness

The Materials Science and Engineering Dept. at UA has initiated and led the development of the Additive Manufacturing Initiative (AMI ami.arizona.edu) that includes faculty affiliates and research activities from across the University (including the Colleges of Engineering, Science, Optical Sciences, Architecture, Medicine, and the Lunar and Planetary Lab). Moreover, the Initiative is leading the development of a new state-wide partnership in AM with ASU and NAU. The focus on AM at UA and the development of the proposed minor was motivated by discussions with regional industrial partners (including Honeywell Aerospace, PADT, Raytheon) who recognize the need for workforce development in this rapidly evolving advanced manufacturing method and, indeed, strongly support efforts in AM education and training through senior capstone project funding, for example. The minor will also provide a new mechanism for student credit transfer and curriculum access in partnership with Pima Community College. In addition to existing transfer opportunities with PCC¿s Engineering program, the AM minor will also directly connect to the Applied Technology (AT) program at PCC, leveraging an established manufacturing-based curriculum and large-scale teaching facility. This broad-based interest and support from the manufacturing community, the established major and minor curriculum offerings both regionally (ASU, CSM, UTEP) and nationally, as well as the opportunity to broaden UA¿s partnership with PCC provides the strong impetus to offer such a minor. The

minor will provide a state-of-the-art educational and professional preparatory option for our CoE majors in an area of significant impact in the engineering field as well as develop new interest and enhanced recruitment opportunities in the College.

Arizona University System

NBR	PROGRAM	DEGREE	#STDNTS	LOCATION	ACCRDT

Peer Comparison

see attached chart

Faculty & Resources

Faculty

Current Faculty:

INSTR ID	NAME	DEPT	RANK	DEGREE	FCLTY/%
02303709	David Poirier	2804	Professor	Doctor of Philosophy	10.00
02706391	Muluneh Yitayew	1230	Professor	Doctor of Philosophy	10.00
04102643	Cholik Chan	2305	Professor	Doctor of Philosophy	10.00
13907288	Barrett Potter	2804	Professor	Doctor of Philosophy	10.00
15108087	Douglas Loy	2804	Professor	Doctor of Philosophy	10.00
15305415	Samy Missoum	2305	Professor	Doctor of Philosophy	10.00
17106027	Erica Corral	2804	Assoc. Prof	Doctor of Philosophy	10.00
17109846	Jian Liu	2302	Assoc. Prof	Doctor of Philosophy	10.00
22052002	Zoltan Szabo	2305	Adj. Instor.	Doctor of Philosophy	10.00
22084791	Andrew Wessman	2804	Assit. Prof	Doctor of Philosophy	10.00

Additional Faculty:

none

Current Student & Faculty FTE

DEPARTMENT	UGRD HEAD COUNT	GRAD HEAD COUNT	FACULTY FTE
2804	51	25	14.00

Projected Student & Faculty FTE

	UGRD HEAD COUNT			GRAD HEAD COUNT			FACULTY FTE		
DEPT	YR 1	YR 2	YR 3	YR 1	YR 2	YR 3	YR 1	YR 2	YR 3
2804	51	55	60	25	30	35	14.00	15.00	15.00

Library

Acquisitions Needed:

none

Physical Facilities & Equipment

Existing Physical Facilities:

existing facilities adequate.

Additional Facilities Required & Anticipated:

none

Other Support

Other Support Currently Available:

existing faculty and staffing is sufficient. This minor draws from the existing student major population

Other Support Needed over the Next Three Years:

none

Comments During Approval Process

6/30/2020 8:16 AM

DEYMIER

Comments
Approved.

6/30/2020 12:28 PM

SON

Comments
Approved.

7/14/2020 1:15 PM

DBOCCELLI

Comments
Approved.

8/27/2020 12:31 PM

KITTFP

Comments
Approved.

9/11/2020 1:43 PM

PEIWEN

Comments
Approved.

12/10/2020 12:43 PM

BAYGENTS

Comments
Met with Prof. B.G. Potter. 1. Agreed that we would remove MSE 220 from the list of "anchor" courses and replace with MSE 440. Would prefer to retain this course as an elective choice for students in the minor, if permissible (course is Tier 2 GenEd/NATS course) 2. Also agreed that we would insert a stipulation that a student could use either BE 221 or AME 211, but not both, to satisfy requirements for the minor. The overlap between the courses is such that a student should choose one (and not use the other as an elective). 3. Discussed creating an UG Certificate on additive (or advanced) manufacturing, available to non-degree-seeking students, with an articulated pathway from Pima CC to UA. 4. Also discussed need to promote the minor to engineering FR and prospective engineering students. The work-force-ready aspects of this minor will have appeal to many students.

12/10/2020 12:43 PM

BAYGENTS

Comments
Approved.

12/10/2020 3:22 PM

STATENM

Comments
Approved.

THE UNIVERSITY OF ARIZONA

NEW ACADEMIC PROGRAM-STANDALONE UNDERGRADUATE MINOR
ADDITIONAL INFORMATION FORM

I. MINOR DESCRIPTION– provide a marketing/promotional description for the proposed minor. Include the purpose, nature, and highlights of the curriculum, faculty expertise, etc. The description should match departmental and college websites, handouts, promotional materials, etc.

The University of Arizona College of Engineering is pleased to offer a College-wide minor in Additive Manufacturing (AM). Additive Manufacturing (or 3-D Printing) has become an enabling product realization approach that provides fundamentally new opportunities for the rapid design and fabrication of parts used in applications ranging from aerospace and mechanics to biological systems and optics. Knowledge of AM methods and their application is fast becoming a critical element of engineering practice across multiple disciplines. In an effort to address this need, the CoE AM minor provides the student with the foundational principles of AM processes and the computer-aided design capabilities necessary to implement these technologies. In addition, students may focus the balance of the minor in specific themes, drawing from a broad collection of elective course offerings, spanning multiple engineering disciplines, including the materials science of AM, systems-level integration of AM capabilities, process control in AM, and computational modeling. In this regard, the minor offers CoE students a unique opportunity to augment their major engineering curriculum toward increased competitiveness in a manufacturing area with a critical role in the 4th industrial revolution.

II. **NEED FOR THE MINOR/JUSTIFICATION**- provide market analysis data or other tangible evidence of the need for and interest in the proposed minor. This might include results from surveys of current students, alumni, and/or employers or reference to student enrollments in similar programs in the state or region. Curricular Affairs can provide a job posting/demand report by skills obtained/outcomes of the proposed minor. Please contact Martin Marquez to request the report for your proposal.

There is broad regional, national and international interest in Additive Manufacturing processes, materials, and technologies. Over seventy AM or 3DP recent centers and educational programs have been established to-date internationally (see https://additivemanufacturingtoday.com/colleges-universities-with-additive-manufacturing-3d-printing-programs?cat_id=81&view=listcats). Within the US, established programs exist at, for example ASU, MIT, UTEP, CSM, Penn State, Case Western Reserve, University of Florida, Georgia Tech, and Missouri S&T illustrating the broad interest in the field and the presence of an important market for these curricula. The Materials Science and Engineering Dept. at UA has initiated and led the development of the Additive Manufacturing Initiative (AMI – ami.arizona.edu) that includes faculty affiliates and research activities from across the University (including the Colleges of Engineering, Science, Optical Sciences, Architecture, Medicine, and the Lunar and Planetary Lab). Moreover, the Initiative is leading the development of a new state-wide partnership in AM with ASU and NAU. The focus on AM at UA and the development of the proposed minor was motivated by discussions with regional industrial partners (including Honeywell Aerospace, PADT, Raytheon) who recognize the need for workforce development in this rapidly evolving advanced manufacturing method and, indeed, strongly support efforts in AM education and training through senior capstone project funding, for example. The minor will also provide a new mechanism for student credit transfer and curriculum access in partnership with Pima Community College. In addition to existing transfer opportunities with PCC's Engineering program, the AM minor will also directly connect to the Applied Technology (AT) program at PCC, leveraging an established manufacturing-based curriculum and large-scale teaching facility.

This broad-based interest and support from the manufacturing community, the established major and minor curriculum offerings both regionally (ASU, CSM, UTEP) and nationally, as well as the opportunity to broaden UA's partnership with PCC provides the strong impetus to offer such a minor. The minor will provide a state-of-the-art educational and professional preparatory option for our CoE majors in an area of significant impact in the engineering field as well as develop new interest and enhanced recruitment opportunities in the College.

III. MINOR REQUIREMENTS– complete the table below by listing the minor requirements, including minimum number of credit hours, required core, electives, and any special requirements. Note: information in this section must be consistent throughout the proposal documents (comparison charts, curricular/assessment map, etc.). Delete the EXAMPLE column before submitting/uploading.

Minimum total units required	18	EXAMPLE 18
Minimum upper-division units required	9	9
Total transfer units that may apply to minor	9	9
List any special requirements to declare/admission to this minor (completion of specific coursework, minimum GPA, interview, application, etc.)	-Complete all pre-requisite coursework	-Meet with departmental interview committee -Complete all pre-requisite coursework
Minor requirements. List all required minor requirements including core and electives. Courses listed must include course prefix, number, units, and title. Mark new coursework (New). Include any limits/restrictions needed (house number limit, etc.). Provide email(s)/letter(s) of support from home department head(s) for courses not owned by your department.	See Appendix A containing AM minor curriculum plan. Letters of Support from Department Heads attached to this package.	List all required coursework. For example: Actuary core: Complete 2 courses (6 units): -(NEW) ACTU 123 (3) Introduction to Actuarial Sciences -(NEW) ACTU 345 (3) Advanced Actuarial Methods Actuary Electives: Complete 12 units from the following. Limit of 3 units from house-numbered coursework may be used towards this requirement :
Internship, practicum, applied course requirements (Yes/No). If yes, provide description.	No	Yes. Complete 3 units of internship or practicum with a local firm

Additional requirements (provide description)	No.	Complete and submit "Actuary Minor Reflection Paper"
Any double-dipping restrictions (Yes/No)? If yes, provide description.	Yes, with major program.	Yes, minor coursework may not double dip with another minor.

IV. CURRENT COURSES–using the table below, list all existing courses included in the proposed minor. You can find information to complete the table using the UA course catalog or UAnalytics (Catalog and Schedule Dashboard> "Printable Course Descriptions by Department" On Demand Report; right side of screen). If the courses listed belong to a department that is not a signed party to this implementation request, upload the department head's permission to include the courses in the proposed minor and information regarding accessibility to and frequency of offerings for the course(s). Upload letters of support/emails from department heads to the "Letter(s) of Support" field on the UAccess workflow form. Add rows to the table, as needed.

Course prefix and number (include cross-listings)	Units	Title	Course Description	Pre-requisites	Modes of delivery (online, in-person, hybrid)	Typically Offered (F, W, Sp, Su)	Dept signed party to proposal? (Yes/No)
MSE 222	3	**Introduction to Materials Science and Engineering I**	Introduction to the structure of materials and how structure influences properties. Elementary crystallography, crystal chemistry, and microstructure effects are covered. Examples are taken from all classes of materials: metals, semiconductors, ceramics, polymers, glasses, and composites.	*Chem 151; MSE 110 or Chem 152; Math 122B or Math 125*	In-person; online	F	Yes
MSE 331r	3	**Fundamentals of Materials for Engineers**	Principles which underlie and relate the behavior, properties and processing of materials to their engineering applications.	*Chem 151 and PHYS 103*	In-person	F,Sp	Yes
MSE 220	3	**Make it…Green! 3-D Printing and the Environment**	3-D Printing (also known as Additive Manufacturing (AM)) involves the direct conversion of 3D computer aided designs into physical objects with applications impacting such fields as aerospace, architecture, microelectronics, medicine, and space exploration. It represents a revolution in the manufacturing and distribution of products and systems to the consumer while offering a dramatic potential for reduction in the environmental impact of product design, development, and	none	In-person	F	Yes

			realization. The course will provide students with direct experience in 3-D printing methods through hands-on, group projects focusing on this unique and growing manufacturing methodology. Students will examine the environmental ramifications of 3-D printing for the large and small-scale production of objects by exploring its impact on the primary stages of the product lifecycle.				
AME 410	3	**Introduction to Additive Manufacturing**	In this course, engineering materials and their properties are first reviewed. Traditional manufacturing such as casting, forming, machining, and joining processes are introduced and discussed. Additive manufacturing is then presented. Both general process chain and specific processes are presented (e.g. photopolymerization, powder bed fusion process). Materials properties of each manufacturing process are examined and compared to each other. Design and optimization for AM is highlighted. Real engineering applications are reviewed and discussed. A final project is required so that student can gain experiences in the entire AM process.	*AME 313, MSE 331r, and (BE 221 or AME 211)*	In-person	F,Sp	Yes
SIE 383	3	**Integrated Manufacturing Systems**	Introduction to the integrated manufacturing enterprise and automation. Topics include computer-aided design, process planning, computer numerical control machining, machine vision, application of robots and automation.	*CHEM 103A, PHYS 141, CAD Drawing experience*	In-person, online	Sp	Yes
BE/ENGR 221	3	**Introduction to Computer Aided Design**	Introduction to computer aided design concepts and techniques. Two and three-dimensional drawing presentation, methods of graphical	None	In-person	F, Sp	Yes

			communications, data analysis, design synthesis and production methods.				
AME 211 (Pima CC transfer (CAD270, MAC155, and MAC257 (combined))	3	**Computer Aided Drafting and Manufacturing**	The aim of this course is to provide the students with fundamentals in mechanical drafting and how it relates to manufacturing (CNC and additive manufacturing) and modern computational tools such as finite element analysis. SolidWorks will be used as the main learning and practice tool.	*Math 122B*	In-person	F, Sp	Yes
MSE 460	3	**Materials Science of Polymers**	Introduction to physical properties of polymers. Microstructure, crystallization, rheology, relaxation and mechanical properties.	*MSE 223R or MSE 331R*	In-person, online	Sp	Yes
SIE 406	3	**Quality Engineering**	Quality, improvement and control methods with applications in design, development, manufacturing, delivery and service. Topics include modern quality management philosophies, engineering/statistical methods (including process control, control charts, process capability studies, loss functions, experimentation for improvement) and TQM topics (customer driven quality, teaming, Malcolm Baldridge and ISO 9000).	*Adv. Standing: Engineering, SIE 305*	In-person, online?	Sp	Yes
AME 463	3	**Finite Element Analysis with ANSYS**	Fundamentals of finite element analysis, model generation, solution procedure, post processing in ANSYS for problems from various disciplines such as structural thermal or fluids.	*AME 301 and AME 302 and (AME 324A or CE 215)*	In-person	Sp	Yes
CE 402	3	**Introduction to Finite Element Methods**	Theory and formulation procedures: energy and residual. One-dimensional problems: stress analysis in axial structures, steady and transient fluid and heat flow, consolidation, wave-propagation, beam-column. Two-dimensional problems: field and	*Adv Standing: Engineering. CE 303*	In-person	F, Sp	Yes

			plane/axisymmetric, use of computer codes for solution to typical problems.				
MSE 414	3	**Solidification of Casting**	Principles of metal castings while applying fundamentals of transport phenomena and materials science and engineering. Students work in teams on three projects that provide experience in engineering design and hands-on use of the Metal Casting Laboratory. Taught every two years.	*AME 432 or CHEE 305, MSE 415; MSE 331r or MSE 110*	In-person	F	yes
MSE 455	3	**Physical metallurgy and processes of alloys**	Brief review of metallic crystal structures, application of binary diagrams, equilibrium and nonequilibrium solidification, effects of alloy elements on important transformations in steel, isothermal transformation diagrams and continuous cooling diagrams. Processing aspects include heat treating, heat transfer during cooling and quenching, segregation effects, and surface hardening techniques.	*MSE 223R or MSE 331R*	In-person	F	Yes
MSE 440	3	**Metal Additive Manufacturing**	Metal additive manufacturing is a technology experiencing rapid adoption across a number of industries where high design complexity, customization and rapid turn times are desirable such as aerospace, biomedical, motorsports and functional prototyping. This course will examine the various industrially relevant metal additive manufacturing processes, the fundamental interactions between processing parameters, alloy chemistries, materials structures and application, and the post processing operations and computation tools used to obtain finished parts that meet engineering design intent.	*MSE 110, MSE 220 or MSE 331R*	In-person	Sp	Yes

V. NEW COURSES NEEDED – using the table below, list any new courses that must be created for the proposed program. If the specific course number is undetermined, please provide level (ie CHEM 4**). Add rows as needed. Is a new prefix needed? If so, provide the subject description so Curricular Affairs can generate proposed prefix options.

Course prefix and number (include cross-listings)	Units	Title	Course Description	Pre-requisites	Modes of delivery (online, in-person, hybrid)	Status*	Anticipated first term offered	Typically Offered (F, W, Sp, Su)	Dept signed party to proposal? (Yes/No)	Faculty members available to teach the courses
N/A										

*In development (D); submitted for approval (S); approved (A)

Subject description for new prefix (if requested). Include your requested/preferred prefix, if any:

VI. FACULTY INFORMATION- complete the table below. If UA Vitae link is not provided/available, attach a short CV (2-3 pages) to the end of the proposal or upload to the workflow form. UA Vitae profiles can be found in the UA directory/phonebook. Add rows as needed. Delete the EXAMPLE rows before submitting/uploading. **NOTE: full proposals are distributed campus-wide, posted on committee agendas and should be considered "publicly visible". Contact Pam Coonan and Martin Marquez if you have concerns about CV information being "publicly visible".**

Faculty Member	Involvement	UA Vitae link or "CV attached"
EX: Joan Smith	Teach ACTU 123	CV attached
EX: Mike Smith	Teach ACTU 345, Faculty advisor, Internship supervisor	UA Vitae Link
B.G. Potter	Teach MSE 222, 220	https://profiles.arizona.edu/person/bgpotter
D.A. Loy	Teach MSE 220, 460	https://profiles.arizona.edu/person/daloy
A. Wessman	Teach MSE 440	https://profiles.arizona.edu/person/wessman
E. Corral	Teach MSE 331R	https://profiles.arizona.edu/person/elcorral
D. Poirier	Teach MSE 414, 455	https://profiles.arizona.edu/person/poirierd
Cholik Chan	Teach AME 410	https://profiles.arizona.edu/person/cholik
Zoltan Szabo	Teach AME 211	CV attached
Muluneh Yitayew	Teach BE/ENGR 221	https://profiles.arizona.edu/person/myitayew
Jian Liu	Teach SIE 406	https://profiles.arizona.edu/person/jianliu
Samy Missoum	Teach AME 463	https://profiles.arizona.edu/person/smissoum

VII. STUDENT LEARNING OUTCOMES AND CURRICULUM MAP—describe what students should know, understand, and/or be able to do at the conclusion of this minor. Work with Office of Instruction and Assessment to create a curricular map using Taskstream. Include your curricular map in this section (refer to Appendix A for sample Curriculum Map generated using Taskstream).

Outcome 1: Demonstrate knowledge of AM technologies and materials and their use for product realization in advanced manufacturing.
Outcome 2: Demonstrate proficiency in computer aided design as applied to 3-D printing methods.
Outcome 3: Assess AM technological challenges in the context of specific engineering applications.

Curriculum Map:

University of Arizona AMS
DEMO AREA

Minor in Additive Manufacturing

Courses and Activities Mapped to Minor in Additive Manufacturing

	Outcome		
	Outcome 1 Demonstrate knowledge of AM technologies and materials and their use for product realization in advanced manufacturing.	Outcome 2 Demonstrate proficiency in computer aided design as applied to 3-D printing methods.	Outcome 3 Assess AM technological options in the context of specific engineering applications.
Courses and Learning Activities			
Core Course (MSE 222 or MSE 331R) AND (MSE 220 or AME 410 or SIE 383) Students take two core courses, selecting one from each of these two groupings.Faculty will use embedded course assignments to assess the outcomes.	A		
Options Course List of courses to choose from Students will complete embedded assessment assignments within the options courses.		A	
Elective course Combination of Three courses Embedded assignments will be aggregated and assessment results compiled.			A
Exit Survey indirect	A	A	A

Legend : **I** Introduced **P** Practiced A Assessed **I/P** Introduced/Prac

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VIII. ASSESSMENT PLAN FOR STUDENT LEARNING- using the table below, provide a schedule for program assessment of intended student learning outcomes 1) while students are in the program and 2) after completion of the minor. Add rows as needed. Delete EXAMPLE row.

Learning Outcomes	Sources(s) of Evidence	Assessment Measures	Data Collection Points
EXAMPLE: Outcome 1: Discern ethical problems, ambiguities, controversies, and assumptions in…	Course-embedded assessments Pre-post student reflection essays; exit surveys; student focus group; alumni surveys	Exams, papers, and other forms of student work Summative critical self-reflections	End of each course End of CHEM 4** course
Outcome 1: Demonstrate knowledge of AM technologies and materials and their use for product realization in advanced manufacturing.	Course-embedded assessments	Final Course Grade average for the two required anchor courses (see curriculum plan). Exit survey	End of courses
Outcome 2: Demonstrate proficiency in computer aided design as applied to 3-D printing methods.	Course-embedded assessments	Final Course Grade in required CAD course (see curriculum plan). Exit survey	End of course
Outcome 3: Assess AM technological challenges in the context of specific engineering applications.	Course-embedded assessments	Final Course Grade average from 3 elective courses (see curriculum plan). Exit survey	End of courses

IX. ANTICIPATED STUDENT ENROLLMENT-complete the table below. What concrete evidence/data was used to arrive at the numbers?

5-YEAR PROJECTED ANNUAL ENROLLMENT					
	1st Year	2nd Year	3rd Year	4th Year	5th Year
Number of Students	28	23	23	27	33

Data/evidence used to determine projected enrollment numbers:

We contacted the two undergraduate minor peer institutions (Colorado School of Mines and Carnegie Mellon) to inquire about their enrollments for the minors they offer in Additive Manufacturing. Their response was that there were few students enrolled since their minors in additive manufacturing were fairly new (only in existence a year or 2 at most). Based on data that is seen for minors within the college of engineering at UA, students tend to minor in departments where they are able to use course requirements that satisfy their major as well as minor requirements. The data that was used to project enrollments for the AM minor consisted in looking at the minor enrollments for students that are minoring in MSE, AME, SIE, BE and CVE (these departments have all approved use of certain courses offered in their department to satisfy AM minor requirements). The data used to project this data was for the past 5 years. An average was taken for each year to project these numbers. (Please see attached table below).

	Minor Program	Enrolled	Degrees Awarded S15			Enrolled	Degrees Awarded S16			Enrolled	Degrees Awarded S17			Enrolled	Degrees Awarded S18			Enrolled	Degrees Awarded S19
Fall 2015	Aerospace Engineering	19	3	Fall 2016	Aerospace Engineering	15	4	Fall 2017	Aerospace Engineering	16	2	Fall 2018	Aerospace Engineering	34	2	Fall 2019	Aerospace Engineering	68	17
	Biosystems Engineering	6			Biosystems Engineering	1			Biosystems Engineering	5			Biosystems Engineering	2			Biosystems Engineering	3	
	Civil Engineering	4			Civil Engineering	2	2		Civil Engineering	1			Civil Engineering	1			Civil Engineering	4	
	Materials Science & Engr	18	5		Materials Science & Engr	16	8		Materials Science & Engr	22	3		Materials Science & Engr	18	8		Materials Science & Engr	13	7
	Mechanical Engineering	76	26		Mechanical Engineering	67	30		Mechanical Engineering	57	21		Mechanical Engineering	60	17		Mechanical Engineering	59	22
	Systems & Industrial Engr	16	9		Systems & Industrial Engr	14	8		Systems & Industrial Engr	16	8		Systems & Industrial Engr	18	10		Systems & Industrial Engr	19	7
	Additive Manufacturing	28	8			23	10			23	7			27	7			33	11

X. ANTICIPATED MINORS AWARDED- complete the table below, beginning with the first year in which minors will be awarded. How did you arrive at these numbers? Take into consideration departmental retention rates.

PROJECTED MINORS AWARDED ANNUALLY					
	1st Year	2nd Year	3rd Year	4th Year	5th Year
Number of Minors	8	10	7	7	11

Data/evidence used to determine number of anticipated minors awarded annually:

The data that was used to project minors awarded for the AM minor consisted in looking at the minor enrollments for students that are minoring in MSE, AME, SIE, BE and CVE (these departments have all approved use of certain courses offered in their department to satisfy AM minor requirements). Data for minors awarded was pulled from UA Analytics for each minor program. An average was taken for each year to project these numbers. (Please see attached table below).

	Minor Program	Enrolled	Degrees Awarded S15			Enrolled	Degrees Awarded S16			Enrolled	Degrees Awarded S17			Enrolled	Degrees Awarded S18			Enrolled	Degrees Awarded S19
Fall 2015	Aerospace Engineering	19	3	Fall 2016	Aerospace Engineering	15	4	Fall 2017	Aerospace Engineering	16	2	Fall 2018	Aerospace Engineering	34	2	Fall 2019	Aerospace Engineering	68	17
	Biosystems Engineering	6			Biosystems Engineering	1			Biosystems Engineering	5			Biosystems Engineering	2			Biosystems Engineering	3	
	Civil Engineering	4			Civil Engineering	2	2		Civil Engineering	1			Civil Engineering	1			Civil Engineering	4	
	Materials Science & Engr	18	5		Materials Science & Engr	16	8		Materials Science & Engr	22	3		Materials Science & Engr	18	8		Materials Science & Engr	13	7
	Mechanical Engineering	76	26		Mechanical Engineering	67	30		Mechanical Engineering	57	21		Mechanical Engineering	60	17		Mechanical Engineering	59	22
	Systems & Industrial Engr	16	9		Systems & Industrial Engr	14	8		Systems & Industrial Engr	16	8		Systems & Industrial Engr	18	10		Systems & Industrial Engr	19	7
	Additive Manufacturing	28	8			23	10			23	7			27	7			33	11

XI. PROGRAM DEVELOPMENT TIMELINE- describe plans and timelines for 1) marketing the minor and 2) student recruitment activities.

The minor already has sufficient courses available to begin accepting students for the Fall of 2020. The new minor will be marketed to existing and new CoE students through CoE website advertising, integration into CoE engineering ambassador tour content, social networking (e.g. departmental Facebook sites, LinkedIn) and via introduction in broadly attended freshman engineering courses (e.g. ENG 102, MSE 110). Such activities will begin with minor approval and continue as standard publicity content for the College moving ahead. The potential for new transfer content and the presence of an AM minor in the UA CoE will also be publicized within Pima CC in both the Engineering and Applied Technology programs to alert those students to this additional curriculum opportunity when pursuing a CoE BS degree.

XII. DIVERSITY AND INCLUSION-describe how you will recruit diverse students and faculty to this minor. In addition, describe retention efforts in place or being developed in order to retain students.

As a minor available to CoE discipline majors, the minor will draw from recruitment activities and diversity enhancement strategies already in place at the CoE level for the recruitment of undergraduate majors into the engineering program. Further information can be obtained through the CoE Associate Dean for Academic Affairs

Appendix A. College of Engineering AM minor curriculum plan

Additive Manufacturing Undergraduate Minor
Materials Science and Engineering
College of Engineering
University of Arizona

General requirements:

18 Credits – (minimum of) 9 upper division credits required

Students are assumed to have successfully completed foundational, freshman-level coursework consistent with major program requirements

Required courses (9 credits):

Two "anchor" courses + CAD-related competency course.

Select 2 anchor courses from the following:

ONE from this list:

MSE 222 – Introduction to Materials Science and Engineering I
Prereqs: Chem 151; MSE 110 or Chem 152; Math 122B or Math 125

MSE 331r – Fundamentals of Materials for Engineers
Prereqs: Chem 151 and PHYS 103

ONE from this list:

MSE 220 – Make it…Green! 3-D Printing and the Environment
Prereqs: none

AME 410 – Introduction to Additive Manufacturing
Prereqs: AME 313, MSE 331r, and (BE 221 or AME 211)

SIE 383 - Integrated Manufacturing Systems
Prereqs: CHEM 103A, PHYS 141, CAD Drawing experience.

Select 1 CAD-related course

BE/ENGR 221 – Introduction to Computer Aided Design
Prereqs: none

AME 211: Computer Aided Drafting and Manufacturing (or PCC transfer (CAD270, MAC155, and MAC257 (combined))
Prereqs: Math 122B

Electives (9 credits): choose from following course listing (can double count from major degree electives as allowed by CoE and department program requirements)

Existing UA Courses:

MSE 220: 3-D Printing and the Environment (approved for NATS Tier 2 Gen Ed)

MSE 460: Materials Science of Polymers

Prereqs: MSE 223R or MSE 331R

SIE 406: Quality Engineering

Prereqs: Adv. Standing: Engineering, SIE 305

AME 211: Computer Aided Drafting and Manufacturing

Prereqs: Math 122B

AME 410: Introduction to Additive manufacturing

Prereqs: AME 313, MSE 331r, and (BE 221 or AME 211)

AME 463: Finite Element Analysis with ANSYS

Prereqs: AME 301 and AME 302 and (AME 324A or CE 215).

CE 402 – Introduction to Finite Element Methods

Prereqs: Adv Standing: Engineering. CE 303.

MSE 414 – Solidification of Casting

Prereqs: AME 432 or CHEE 305, MSE 415; MSE 331r or MSE 110

MSE 455 – Physical metallurgy and processes of alloys

Prereqs: MSE 223R or MSE 331R

MSE 440: Metal Additive Manufacturing (Fall, 2020)

Prereqs: MSE 110, MSE 220 or MSE 331R

UA Courses Envisioned or Under Development:

SIE XXX: Process Modeling and Digital Manufacturing (under development)

SIE/AME XXX: Design for AM (TBD)

ENGR 2XX: The Fourth Industrial Revolution

MSE 2XX: Metallurgical Processing Methods

Undergraduate Minor Peer Comparison Chart

	Proposed UA Program:	Peer 1:	Peer 2:
Minor name, institution	Minor in Additive Manufacturing (AM)	Colorado School of Mines: Minor in Advanced Manufacturing	Carnegie Mellon: AM designated minor
Current# of enrolled students	[redacted]	?	?
Minor program description	The University of Arizona College of Engineering is pleased to offer a College-wide minor in Additive Manufacturing (AM). Additive Manufacturing (or 3-D Printing) has become an enabling product realization approach that provides fundamentally new opportunities for the rapid design and fabrication of parts used in applications ranging from aerospace and mechanics to biological systems and optics. Knowledge of AM methods and their application is fast becoming a critical element of engineering practice across multiple disciplines. In an effort to address this need, the CoE AM minor provides the student with the foundational principles of AM processes and the computer-aided design capabilities necessary to implement these technologies. In addition, students may focus the balance of the minor in specific themes, drawing from a broad collection of elective course offerings, spanning multiple engineering disciplines, including the materials science of AM, systems-level integration of AM capabilities, process control in AM, and computational modeling. In this regard, the minor offers CoE students a unique opportunity to augment their major engineering curriculum toward increased competitiveness in a manufacturing area with a critical role in the 4th industrial revolution.	https://manufacturing.mines.edu/minor-or-area-of-special-interest/ The Advanced Manufacturing Program provides students with the interdisciplinary skills needed to apply cutting-edge manufacturing techniques within a wide range of industries. Throughout the program, students work with state-of-the-art industrial equipment and open-platform fabrication systems with a focus on additive manufacturing. The Advanced Manufacturing teaching lab is dedicated to the program, allowing students to explore various equipment and systems. Within this lab, students have the option to work with polymers, metals, ceramics and biological materials, while optimizing structural design and capturing and interpreting important process data. The Advanced Manufacturing Program offers an Area of Special Interest and a Minor for undergraduate students.	https://engineering.cmu.edu/education/undergraduate-programs/curriculum/additive-manufacturing-minor.html The objective of the Designated Minor in Additive Manufacturing is to provide the student with a background in the engineering science that applies to additive manufacturing (also known as 3D printing), from part design through additive processes, to properties and component performance. Particular emphasis is given to metals additive manufacturing, due to its rapidly growing impact on manufacturing across multiple industries, and the need for talent in this area. The minor is open to students in all engineering majors.
Target careers	- process engineers - production engineers - manufacturing design	- process engineers - production engineers - manufacturing design	- process engineers - production engineers - manufacturing design
Minimum total units required	18 credit hours	18 credit hours	54 units (5 courses)
Minimum upper-division units required	9 credit hours	not clear from website	not clear from website
Total transfer units that may apply to minor	3 credit hours	unknown	unknown
List any special requirements to declare/admission to this minor (completion of specific coursework, minimum GPA, interview, application, etc.)	Complete all pre-requisite coursework; GPA of 3.0 or higher	Enrolling students should have a GPA of 3.0 or higher (current	College of Engineering student.
Minor requirements. List all minor requirements including core and electives. Courses listed must include course prefix, number, units, and title. Mark new coursework (New). Include any limits/restrictions needed (house number limit, etc.). Provide email(s)/letter(s) of support from home department head(s) for courses not owned by your department.	General requirements: 18 Credits – (minimum of) 9 upper division credits required Students are assumed to have successfully completed foundational, freshman-level coursework consistent with major program requirements Required courses (9 credits): Two "anchor" courses + CAD-related competency course. Select 2 anchor courses from the following: MSE 222 – Introduction to Materials Science and Engineering I OR Prereqs: Chem 151; MSE 110 or Chem 152; Math 122B or Math 125 MSE 331r – Fundamentals of Materials for Engineers Prereqs: Chem 151 and PHYS 103 MSE 220 – Make it…Green! 3-D Printing and the Environment Prereqs: none AME 410 – Introduction to Additive Manufacturing Prereqs: AME 313, MSE 331r, and (BE 221 or AME 211) SIE 383 - Integrated Manufacturing Systems Prereqs: CHEM 103A, PHYS 141, CAD Drawing experience. Select 1 CAD-related course BE/ENGR 221 – Introduction to Computer Aided Design Prereqs: none AME 211: Computer Aided Drafting and Manufacturing (or PCC transfer (CAD270, MAC155, and MAC257 (combined)) Prereqs: Math 122B	Minor in Advanced Manufacturing: 18 credit hours; Required: AMFG 401 Introduction to Additive Manufacturing (3 credit hours) and 15 credit hours* selected from the list below (effective Fall 2020);;AMFG 401 Intro to Additive Manufacturing (3.0) MEGN 381 Manufacturing Processes (3.0) MEGN 412 Advanced Mechanics of Materials (3.0) AMFG 421 Design for Additive Manufacturing (3.0) AMFG 422 Lean Manufacturing (3.0) AMFG 511** Data-Driven Materials Manufacturing (3.0) AMFG 531** Materials for Additive Manufacturing (3.0) FEGN 525** Advanced FEA Theory & Practice (3.0) FEGN 526** Static and Dynamic Applications in FEA (3.0)	Core courses: 39-601/24-632 Special Topics: Additive Manufacturing Processing and Product Development; 39-602/27-765 Materials Science for Additive Manufacturing; 39-603 Additive Manufacturing Laboratory. Electives: Mathematics (21-XXX) 21-660 Introduction to Numerical Analysis 21-690 Methods of Optimization Biomedical Engineering (42-XXX) 42-411/27-411 Engineering Biomaterials 42-444 Medical Devices 42-474 Introduction to Biophotonics 42-612/27-520 Tissue Engineering 42-613/27-570 Molecular and Micro-Scale Polymeric Biomaterials in Medicine 42-640/24-658 Computational Bio-Modeling and Visualization 42-647/24-659 Continuum Biomechanics: Solid and Fluid Mechanics of Physiological Systems 42-648 Cardiovascular Mechanics 42-663 Computational Methods in BME 42-698B Stem Cell Engineering Chemical Engineering (06-XXX) 06-462 Optimization Modeling and Algorithms 06-463 Chemical Product Design
Internship, practicum, applied course requirements (Yes/No). If yes, provide description.	No	Nothing beyond above requirements	Nothing beyond above requirements.
Additional requirements (provide description)	No	Nothing beyond above requirements	Nothing beyond above requirements.

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BUDGET PROJECTION FORM

Note - the proposed minor provides an opportunity for students across the College of Engineering to collect existing courses related to additive manufacturing into a new minor focus. As such, no additional budget is required to provide this opportunity. While we do anticipate that having such a minor offering will be helpful for recruitment, we will be drawing on existing College of Engineering recruitment for the existing major programs and departments rather than initiating new activities focusing only on this minor. Given this background, it is not clear how best to respond to the request for budget projections.

Name of Proposed Program or Unit: Minor in Additive Manufacturing

Budget Contact Person:	Projected **1st Year** 20 ___ - 20 ___	 **2nd Year** 20 ___ - 20 ___	 **3rd Year** 20 ___ - 20 ___
METRICS			
Net increase in annual college enrollment UG			
Net increase in college SCH UG			
Net increase in annual college enrollment Grad			
Net increase in college SCH Grad			
Number of enrollments being charged a Program Fee			
New Sponsored Activity (MTDC)			
Number of Faculty FTE			
FUNDING SOURCES			
Continuing Sources			
UG RCM Revenue (net of cost allocation)			
Grad RCM Revenue (net of cost allocation)			
Program Fee RCM Revenue (net of cost allocation)			
F and A Revenues (net of cost allocations)			
UA Online Revenues			
Distance Learning Revenues			
Reallocation from existing College funds (attach description)			
Other Items (attach description)			
Total Continuing	$ -	$ -	$ -
One-time Sources			
College fund balances			
Institutional Strategic Investment			
Gift Funding			
Other Items (attach description)			
Total One-time	$ -	$ -	$ -
TOTAL SOURCES	$ -	$ -	$ -
EXPENDITURE ITEMS			
Continuing Expenditures			
Faculty			
Other Personnel			
Employee Related Expense			
Graduate Assistantships			
Other Graduate Aid			
Operations (materials, supplies, phones, etc.)			
Additional Space Cost			
Other Items (attach description)			
Total Continuing	$ -	$ -	$ -
One-time Expenditures			
Construction or Renovation			
Start-up Equipment			
Replace Equipment			
Library Resources			
Other Items (attach description)			
Total One-time	$ -	$ -	$ -
TOTAL EXPENDITURES	$ -	$ -	$ -
Net Projected Fiscal Effect	$ -	$ -	$ -

THE UNIVERSITY OF ARIZONA

College of Engineering
Department of Aerospace &
Mechanical Engineering

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April 3, 2020

Prof. B.G. Potter, Jr.
Materials Science and Engineering Dept.

Dear B.G.,

Thank you for your recent message concerning the development of a new College of Engineering minor in Additive Manufacturing. As a home department for one required course and two elective courses that have been included in the initial curriculum listing for the minor, this letter serves to confirm our support for this new curriculum opportunity in the College. Further, the courses involved in the minor are regularly offered as part of our existing curriculum and seats are generally available in these classes.

Sincerely,

Peiwen 'Perry' Li

THE UNIVERSITY OF ARIZONA
COLLEGE OF AGRICULTURE & LIFE SCIENCES
COLLEGE OF ENGINEERING
Biosystems Engineering

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Fax: 520-621-3963

http://be.arizona.edu

April 28, 2020

Prof. B.G. Potter, Jr.
Materials Science and Engineering Dept.

Dear B.G.,

Thank you for your message concerning the development of a new College of Engineering minor in Additive Manufacturing. As a home department for one of the courses included in the initial curriculum listing for the minor, this letter serves to confirm our support for this new curriculum opportunity in the College. Further, the course involved in the minor is regularly offered as part of our existing curriculum and seats are available in this course.

Sincerely,

K. L. Farrell-Poe

Kathryn L. Farrell-Poe
Head, Specialist, and Professor

THE UNIVERSITY OF ARIZONA
College of Engineering

April 28, 2020

Prof. B.G. Potter, Jr.
Materials Science and Engineering Dept.

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Sincerely,

Dominic Boccelli
Professor and Department Head
Department of Civil and Architectural Engineering and Mechanics

THE UNIVERSITY OF ARIZONA
College of Engineering

April 3, 2020

Prof. B.G. Potter, Jr.
Materials Science and Engineering Dept.

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Sincerely,

Young-Jun Son, Ph.D.
Professor and Head of Department of Systems and Industrial Engineering