UNIT REPORT

Energy Systems Research Center - Final Annual Report

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Definition of Unit: Center for Energy Systems Research (CESR)

Start: 07/01/2016

End: 06/30/2017

Providing Department: Energy Systems Research Center

Department/Unit Contact: Satish Mahajan

Mission/Vision/Goal Statement:

Mission: The Center for Energy Systems Research (CESR) was established to advance and apply scientific and engineering knowledge and academic programs associated with energy systems and in particular with electric power while supporting the instructional program of Tennessee Technological University (TTU). Research efforts, both theoretical and experimental, are focused on solving current and anticipated problems associated with energy systems. Special emphasis is given to the needs of the electric power industry.

Vision: The center will be known and be recognized nationally for its research contributions in energy systems and Infrastructure areas.

Goals: The 5 current Goals have been developed on the basis of the mission of the Center. The numerical objectives have been arrived at using historical data with a view on advancement towards reaching the vision.

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Providing Department: Energy Systems Research Center

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Vision: The center will be known and be recognized nationally for its research contributions in energy systems and Infrastructure areas.

Goals: The 5 current Goals have been developed on the basis of the mission of the Center. The numerical objectives have been arrived at using historical data with a view on advancement towards reaching the vision.

Goal 1. Increase research activity in the areas of the Center

Progress: Completed

Define Goal:

Increase research activity in the areas of the Center

Intended Outcomes / Objectives:

1. Generate external funding that will contribute to the long term growth and sustainability of the Center. As a minimum, the external funding generated per year by the center faculty should match the state funding.
2. The number of Journal publications and conference presentations will be at least 20 each.

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Goal 2. Increase Student Research Activity

Progress: Completed

Define Goal:

Increase Student Research Activity

Intended Outcomes / Objectives:

1. Increase the number of MS and Ph.D. graduates in the strategic research areas of the Center by 25% during the next three years.
2. Support at least two undergraduate research projects per year in the areas related to energy systems.

Goal 2. Increase Student Research Activity

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Define Goal:

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1. Increase the number of MS and Ph.D. graduates in the strategic research areas of the Center by 25% during the next three years.
2. Support at least two undergraduate research projects per year in the areas related to energy systems.

Goal 3. Increase Collaborative Research

Progress: Completed

Define Goal:

Increase collaborative research

Intended Outcomes / Objectives:

Develop and submit two collaborative proposals with interdisciplinary focus. The number of collaborative proposals submitted per year should be at least two per year.

Goal 3. Increase Collaborative Research

Progress: Completed

Define Goal:

Increase collaborative research

Intended Outcomes / Objectives:

Develop and submit two collaborative proposals with interdisciplinary focus. The number of collaborative proposals submitted per year should be at least two per year.

Goal 4. Add Laboratory Facilities

Progress: Completed

Define Goal:

Add laboratory facilities.

Intended Outcomes / Objectives:

1. Add equipment/capabilities to Smart Grid Research Laboratory.

Goal 4. Add Laboratory Facilities

Progress: Completed

Define Goal:

Add laboratory facilities.

Intended Outcomes / Objectives:

1. Add equipment/capabilities to Smart Grid Research Laboratory.

Goal 5. Increase Outreach Activities

Progress: Completed

Define Goal:

Increase Outreach Activities.

Intended Outcomes / Objectives:

1. Organize a minimum of two seminars by external speakers per year.

Goal 5. Increase Outreach Activities

Progress: Completed

Define Goal:

Increase Outreach Activities.

Intended Outcomes / Objectives:

1. Organize a minimum of two seminars by external speakers per year.

Assessment Tool 1: External grants activated

Goal/ Outcome/ Objective: Goal 1 and Goal 3

Type of Tool: Tracking Spreadsheet

Frequency of Assessment: Annually

Rationale:

External grants activated indicate success in bringing funded research into the university, the result of which will benefit students, the scientific body of knowledge as a whole, and the funding source itself by solving some research problem. It does not address the idea that a bigger project may be better or more smaller projects is better but it does give us a general measure to compare progress. Hopefully some of these projects will also represent collaborative efforts but this tool is not a direct metric of collaboration.

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to compare progress. Hopefully some of these projects will also represent collaborative efforts but this tool is not a direct metric of collaboration.

Assessment Tool 2: Number of Journal Publications and Conference Publications

Goal/ Outcome/ Objective: Goal 1 and Goal 2 and Goal 3

Type of Tool: Tracking Spreadsheet

Frequency of Assessment: Annually

Rationale:

Papers represent the increase in knowledge from research activities. By concentrating on journal and peer reviewed conference papers the quality of the research is acknowledged by peers in the field of study. By examining the list of authors on these publications we can get a measure of the success in the collaboration goal.

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Assessment Tool 3: Number of M.S. and Ph.D. graduates during the year

Goal/ Outcome/ Objective: Goal 1 and Goal 2 and Goal 3

Type of Tool: Tracking Spreadsheet

Frequency of Assessment: Annually

Rationale:

If the graduates this year took a long time getting their degrees then this measure might not directly correlate to effectiveness in achieving the goals but on average this assessment tool is expected to historically follow the quantity of research achieved in the center. By examining the graduate committee for each student we can get an indication of the amount of collaborative research.

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Assessment Tool 4: Number of M.S. and Ph.D. students supported by the center during the year

Goal/ Outcome/ Objective: Goal 1 and Goal 2 and Goal 3

Type of Tool: Tracking Spreadsheet

Frequency of Assessment: Annually

Rationale:

While quantity of students may not directly measure the amount or quality of research being conducted by the center, it is generally perceived that statistically this metric will be relevant to the goals.

Assessment Tool 4: Number of M.S. and Ph.D. students supported by the center during the year

Goal/ Outcome/ Objective: Goal 1 and Goal 2 and Goal 3

Type of Tool: Tracking Spreadsheet

Frequency of Assessment: Annually

Rationale:

While quantity of students may not directly measure the amount or quality of research being conducted by the center, it is generally perceived that statistically this metric will be relevant to the goals.

Assessment Tool 5: Number of undergraduate research projects supported

Goal/ Outcome/ Objective: Goal 1, Goal 2, and Goal 3

Type of Tool: Tracking Spreadsheet

Frequency of Assessment: Annually

Rationale:

Often undergraduate student research results in some of the best innovations since the undergraduate is not burdened knowing what can or can't be done. Including this metric with the others is important to assess the total amount of research being conducted by the center.

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Assessment Tool 6: Number of collaborative proposals submitted

Goal/ Outcome/ Objective: Goal 3

Type of Tool: Tracking Spreadsheet

Frequency of Assessment: Annually

Rationale:

This metric will directly reflect energy expended toward Goal 3. By comparing proposals to activations an effectiveness can ultimately be determined to guide future proposal writing endeavors.

Assessment Tool 6: Number of collaborative proposals submitted

Goal/ Outcome/ Objective: Goal 3

Type of Tool: Tracking Spreadsheet

Frequency of Assessment: Annually

Rationale:

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Assessment Tool 7: Laboratory projects completed/initiated

Goal/ Outcome/ Objective: Goal 4

Type of Tool: Tracking Spreadsheet

Frequency of Assessment: Annually

Rationale:

The number of new laboratories created, renovated, expanded, etc. will directly affect the research infrastructure making more meaningful, up-to-date research possible.

Assessment Tool 7: Laboratory projects completed/initiated

Goal/ Outcome/ Objective: Goal 4

Type of Tool: Tracking Spreadsheet

Frequency of Assessment: Annually

Rationale:

The number of new laboratories created, renovated, expanded, etc. will directly affect the research infrastructure making more meaningful, up-to-date research possible.

Assessment Tool 8: Number of seminars by external speakers and feedback from faculty and students regarding the usefulness of the seminars.

Goal/ Outcome/ Objective: Goal 5

Type of Tool: Tracking Spreadsheet

Frequency of Assessment: Annually

Rationale:

Seminars are important to inform researchers what the current state of the art is in various research disciplines and provide new contact opportunities to promote collaborative efforts. This tool directly reflects the efforts expended toward Goal 5. The feedback from the faculty and students will directly reflect effectiveness of this effort and guide future efforts.

Assessment Tool 8: Number of seminars by external speakers and feedback from faculty and students regarding the usefulness of the seminars.

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Assessment Tool 9: Number of outreach activities planned for the upcoming year with a list of persons to be invited for the activities.

Goal/ Outcome/ Objective: Goal 5

Type of Tool: Tracking Spreadsheet

Frequency of Assessment: Annually

Rationale:

This assessment tool forces Center administration to be forward thinking about Goal 5 since many of the activities related to this goal must be planned well in advance.

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Result for Goal 1. Increase research activity in the areas of the center

Goal/Objective/Outcome Number: 1

Results:

Increase research activity in the areas of the center

- Generate external funding that will contribute to the long term growth and sustainability of the Center. As a minimum, the external funding generated per year by the center faculty should match the state funding.
- The number of Journal publications and conference presentations will be at least 20 each.

This goal intersects the University Flight Plan's Multidisciplinary Research Innovation sub goal. The creation of the Smart Grid and Resilient Infrastructure focus areas is to foster multidisciplinary research efforts. Even if considered to be primarily one department; getting power engineers, communication engineers, cyber security researchers, etc. to focus on a common laboratory for collaborative efforts has resulted in several collaborative proposals being prepared.

The new Center Focus Areas also intersect the University Flight Plan focus areas to Create Distinctive Programs and Invigorate Faculty.

This year we are continuing to report on the fiscal year to reduce reporting efforts by aligning with our other annual report. This also brings us inline with the other centers reporting.

There were 30 total activations which totaled $ 1,414,229.80, an improvement over last year. This is an improvement of ~ 12% over the last year. A full listing of activations can be found in the attachments.

The publications listed in the publications attachment can be summarized for the Center's associated faculty by totalling the 79 conference papers and 50 journal articles which handily surpasses the goal of 20 of each type. Note also 1 patent application, 2 standards, and 4 book chapters were completed. Note that this year's activity corresponds to Fiscal Year while two years ago was a calendar year reporting.

The metrics for publications, patents, and book chapters will be changed for the upcoming year. It will be an average of 3 years and only center personnel will be included instead of all the center faculty associates. This is consistent with reporting done by the other center (CMR) as well as directive given by the new provost to avoid double counting.

Attachments: Attached Files

- SM 3 List of Activations 2017-2018 - with PIs Names.xlsx
- Publications 2017-18.docx

Result for Goal 1. Increase research activity in the areas of the center

Goal/Objective/Outcome Number: 1

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The new Center Focus Areas also intersect the University Flight Plan focus areas to Create Distinctive Programs and Invigorate Faculty. In addition to hosting meetings for each research area to promote collaboration and proposal writing, the Center has initiated several seminars and introductory trips to kick start collaborative research efforts and energize faculty efforts.

A formal opening of the Smart Grid Lab with attendees from TVA, NES, and others was an exceptional opportunity to share a research vision of the new space.

This year we are going back to reporting on the fiscal year to reduce reporting efforts by aligning with our other annual report. This also brings us inline with the other centers reporting.

There were 20 total activations which totaled $1,260,711 , an improvement over last year. This is a significant improvement over last year and the goal's objective.. A full listing of activations can be found in the attachments.

The publications listed in the publications attachment can be summarized for the Center's associated faculty by totalling the 89 conference papers and 48 journal articles which handily surpasses the goal of 20 of each type. Note also 1 technical reports, 1 patent, 2 standards, and 2 book chapters were completed. Note that this year's activity corresponds to Fiscal Year while last

year was a calendar year reporting.

Attachments: Attached Files

- SM 3 List of Activations 2016-2017
- Publications 2016-17 Fiscal Year

Results for Goal 2. Increase Student Research Activity

Goal/Objective/Outcome Number: 2

Results:

Increase Student Research activity

- Increase the number of MS and Ph.D. graduates in the strategic research areas of the Center by 25% during the next three years.
- Support at least two undergraduate research projects per year in the areas related to energy systems.

This goal intersects the University Flight Plan's New Graduate Programs sub goal. Since the Center now has the Smart Grid and Resilient Infrastructure focus areas, graduate degrees resulting from this focused Center attention will yield more hire-able graduates in these areas of recognized national importance.

The number of M.S. and Ph.D. graduates for the Fiscal Year 2016-2017 can be seen in Table 1. The listing of the graduating students Masters Thesis and the Ph.D. Dissertation topics can be found in the attachment.

Though CESR has traditionally focused on graduate research there are several points that can be made about progress toward the Flight Plan focus area for improving the undergraduate student experience. Encouraging faculty to utilize graduate research labs in their undergraduate teaching is the best way to meet this objective.

Forty Eight undergraduate students from a multidisciplinary array of departments conducted research under the umbrella of CESR (see attachment).

The highlighted undergraduate researcher this year is Aaron Bain who greatly helped the new Solar Assistance program funded by the USDA. He went on site surveys, generated reports, and helped spawn a new research endeavor to heat the roots of tomato plants using solar thermal energy.

Increasing student research activity can be partially assessed by the support of students. Students have been supported by the Center in a number of ways including financially, office space, IT support, and R&D Engineering support. Figure 1 shows the historic financial support for the last 5 years with steady increases for the last 4 years.

Table 1. Students supported by the Center in many ways.

Number of Students Supported by the CESR during Fiscal Year 2017-2018			
	B.S.	M.S.	Ph.D.
Graduates		15	0
Financial Support			
Assistantships		15	17
Hourly Student Payroll	48	28	23

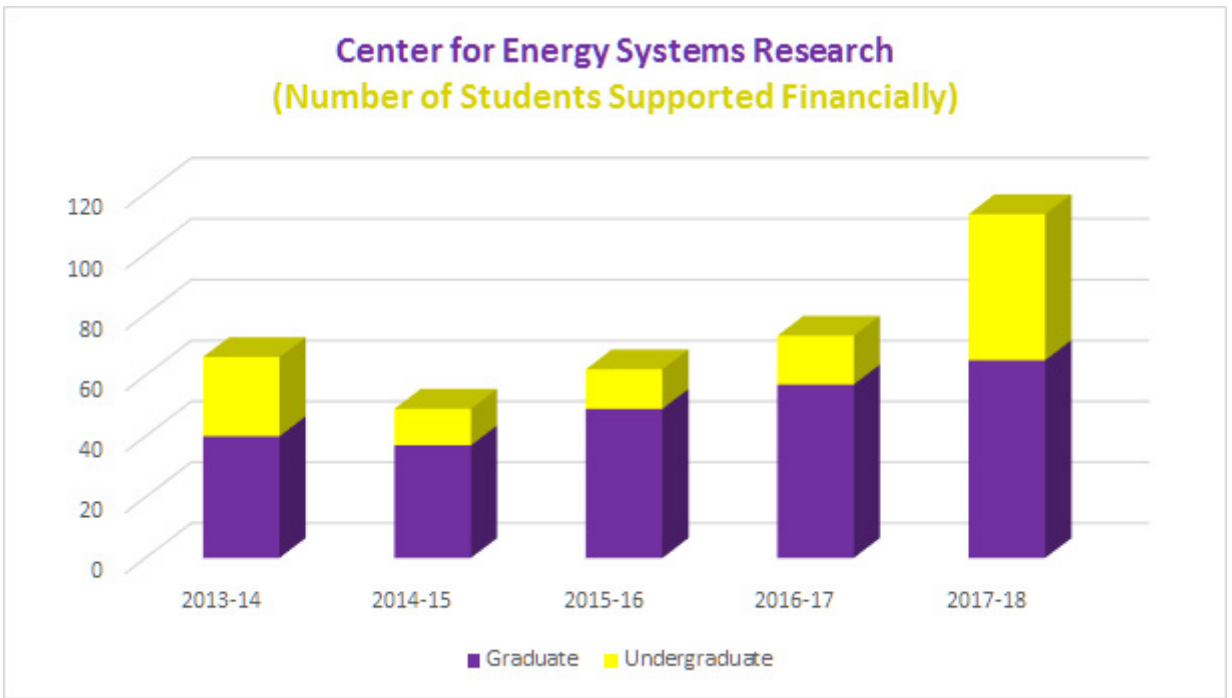

Figure 1 Students Supported for the last 5 years.

Figure 1 appears to support the goal of 25% increase in students as highlighted in Table 2, but it only considers support, not graduates. By looking at Table 3 we can see that chaos ensues and so next year this goal will change but only after deliberate consideration. Goal will be modified to eliminate the # graduates (since the center has no control over that) but the number of graduate students supported by the center will be linked to the amount of external funding generated.

Table 2. Historic support of graduate students

Fiscal Year	MS/PhD Students Supported	% Increase over previous year	% Increase over first year
2014-15	37		
2015-16	49	32.4	32.4
2016-17	57	16.3	54.1
2017-18	65	14.0	75.7

Table 3. Historic graduation of graduate students

Fiscal Year	MS/PhD Students Graduated	% Increase over previous year	% Increase over first year
2014-15	16		
2015-16	9	-43.8	-43.8
2016-17	23	155.6	43.8
2017-18	15	-34.8	-6.3

Attachments: Attached Files

- SM 8 CESR Graduates Degrees Completed 2017-2018.docx
- SM-10 HOURLY STUDENT 2017-2018.docx
- SM-11 Undergraduate Student Research Aug 8 2018.xlsx

Results for Goal 2. Increase Student Research Activity

Goal/Objective/Outcome Number: 2

Results:

Increase Student Research activity

- Increase the number of MS and Ph.D. graduates in the strategic research areas of the Center by 25% during the next three years.
- Support at least two undergraduate research projects per year in the areas related to energy systems.

This goal intersects the University Flight Plan's New Graduate Programs sub goal. Since the Center now has the Smart Grid and Resilient Infrastructure focus areas, graduate degrees resulting from this focused Center attention will yield more hire-able graduates in these areas of recognized national importance.

The number of M.S. and Ph.D. graduates for the Fiscal Year 2016-2017 can be seen in Table 1. The listing of the graduating students Masters Thesis and the Ph.D. Dissertation topics can be found in the attachment.

Though CESR has traditionally focused on graduate research there are several points that can be made about progress toward the Flight Plan focus area for improving the undergraduate student experience. Encouraging faculty to utilize graduate research labs in their undergraduate teaching is the best way to meet this objective.

Seventeen undergraduate students from a multidisciplinary array of departments conducted research under the umbrella of CESR (see attachment).

Each term the Center has recently had the benefit of working with a Freshman Honors student. Giving these students real projects has been rewarding to the student and the center facilities.

- Ashley Hazlett worked on piezo-electric actuators to create a mist for a cooling tower. Initial tests were in a bench top environment with further tests in a laboratory setting with a duct serving as a cooling chimney.

Increasing student research activity can be partially assessed by the support of students. In an attachment you can see lists of students that have been supported by the Center in a number of ways including financially, office space, IT support, and R&D Engineering support. This support is summarized in Table 2.

Table 1. Students supported by the Center in many ways.

Number of Students Supported by the CESR during Fiscal Year 2016-2017			
	B.S.	**M.S.**	**Ph.D.**
Graduates		**16**	**7**
Financial Support			
Assistantships		**18**	**17**
Hourly Student Payroll	**16**	**21**	**23**

In support of the flight plan undergraduate research sub focus area, it is important to note that the Work Study/ Work Scholarship students listed in the attachment were able to participate in the creation of research laboratory facilities as part of their day to day work.

Attachments: Attached Files

SM 8 CESR Graduates Degrees Completed 2016-2017

SM-10 HOURLY STUDENT 16-17
Undergraduate Student Research Aug 5 2017

Results for Goal 3. Increase Collaborative Research

Goal/Objective/Outcome Number: 3

Results:

Increase Collaborative research

- Develop and submit two collaborative proposals with interdisciplinary focus. The number of collaborative proposals submitted per year should be at least two per year.

This goal intersects the University Flight Plan's Multidisciplinary Research Innovation sub goal.

The collaborative proposals listed in the Attachment include 10 proposals with an internal to TTU collaborative aspect, 16 with collaborations with an external to TTU component. There were also 4 project activations with a collaborative component. The CESR also hosted two visiting scholars. This level of collaborative effort readily meets the Center's goal.

We are very proud of the collaborative activations with: the University of Tennessee Knoxville; Vanderbilt University and Purdue University; Vanderbilt University; and The Citadel, The University of Florida, and the Georgia Institute of Technology.

Attachments: Attached Files
2017-2018 Collaboration Efforts CESR Revised Aug 14 2018.xlsx

Results for Goal 3. Increase Collaborative Research

Goal/Objective/Outcome Number: 3

Results:

Increase Collaborative research

- Develop and submit two collaborative proposals with interdisciplinary focus. The number of collaborative proposals submitted per year should be at least two per year.

This goal intersects the University Flight Plan's Multidisciplinary Research Innovation sub goal. The recently granted Autonomous drone for transmission line inspection project through the TBR exemplifies this as not only integrating multiple mechanical and electrical engineering researchers from TTU but also reaching out and collaborating with MTSU researchers with drone expertise.

The collaborative proposals listed in the Attachment include 11 proposals with an internal to TTU collaborative aspect, 10 with collaborations with an external to TTU component. There were also 3 project activations with a collaborative component. Three other collaborative efforts are listed consisting of visiting scholars including a Fulbright scholar. This level of collaborative effort readily meets the Center's goal.

Attachments: Attached Files
2016-2017 Collaboration Efforts CESR

Results for Goal 4. Add Laboratory Facilities

Goal/Objective/Outcome Number: 4

Results:

Add Laboratory Facilities

• Smart Grid Research Laboratory

- Added several power electronics pieces of equipment, motor/generator pairs, and another Opal RT real time digital simulator

- A Capstone group began developing an inverter for last years new solar array installed outside the lab (It already has a set of commercial inverters but the students learn from developing their own.)
- A second capstone group is working on the drone inspections of power lines.
- A solar demonstration system was acquired including 1600 W of solar panels, 400Ah of batteries, battery chargers, mounting hardware, and a off-grid inverter.

• Established a Wireless Power Transfer Laboratory

- It has power electronic circuit design capability, RF amplifiers, portable oscilloscopes, inductive power transfer system, capacitive power transfer systems.

This goal intersects the University Flight Plan's Physical Infrastructure Priorities sub goal and the Technology Service to Students sub goal, and the Technology in Teaching sub goal. Better facilities in areas of national importance like the Smart Grid benefit research, education, and hire-ability of our graduates.

Next year Goal 4 will be changed to expanding the Wireless Power Transfer Laboratory and also improvements to the Geotechnical Engineering Laboratory which falls under Resilient Infrastructure research.

Results for Goal 4. Add Laboratory Facilities

Goal/Objective/Outcome Number: 4

Results:

Add Laboratory Facilities

• Smart Grid Research Laboratory

- Had formal open house with TVA, NES, and others.
- Added Meter Box protection
- Added Industrial Relay and Synchrophasor setup with Opal-RT real time digital simulator.

This goal intersects the University Flight Plan's Physical Infrastructure Priorities sub goal and the Technology Service to Students sub goal, and the Technology in Teaching sub goal. Better facilities in areas of national importance like the Smart Grid benefit research, education, and hire-ability of our graduates.

Results for Goal 5. Increase Outreach Activities

Goal/Objective/Outcome Number: 5

Results:

Increase outreach activities

- Organize a minimum of two seminars by external speakers per year.

This goal intersects the University Flight Plan's Co-Curricular Undergraduate Program sub goal and the Multidisciplinary Research Innovation sub goal. By having research area experts from outside the university come teach seminars, workshops or short courses the students will be exposed to a broader base of information and hopefully promote collaborative efforts from TTU researchers with those at other institutions.

The 3 seminars presented by external speakers in the fiscal year 2017-2018 are listed in the Attachment as well as 1 CESR speaker who had recently joined the team.

Attachments: Attached Files
SEMINAR SERIES 2017-2018.docx

Results for Goal 5. Increase Outreach Activities

Goal/Objective/Outcome Number: 5

Results:

Increase outreach activities

- Organize a minimum of two seminars by external speakers per year.

This goal intersects the University Flight Plan's Co-Curricular Undergraduate Program sub goal and the Multidisciplinary Research Innovation sub goal. By having research area experts from outside the university come teach seminars, workshops or short courses the students will be exposed to a broader base of information and hopefully promote collaborative efforts from TTU researchers with those at other institutions.

The 5 seminars presented in the fiscal year 2016-2017 are listed in the Attachment. A special TVA brainstorming day to discover research areas of mutual interest was held in March 2017.

Attachments: Attached Files
Seminars 2016-2017

New Modifications and Continuing Improvement to Goals/Objectives/Outcomes Item