

Building SSP Expertise into the Next Generation of Engineers Through Competitive Projects

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Acknowledgements

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- Space Solar Power Institute
- Georgia Power
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Background

- Courses Taught
 - Sat. Communications,
 - Antenna Eng. & Lab
 - Microwave Design Lab
 - Senior Design
- GT Research
 - Microwave backscatter
 - RF scavenging sensors
 - Radio wave propagation
 - Wireless power transfer



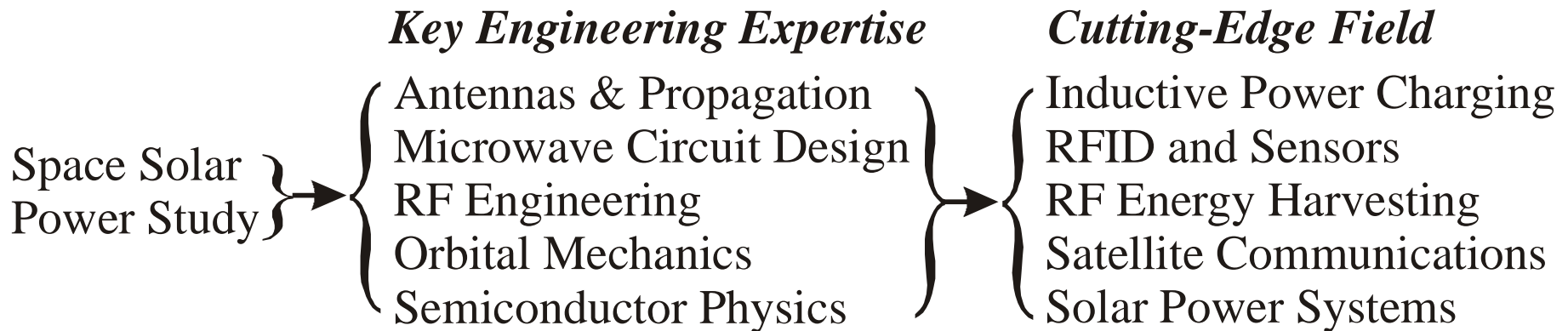
Goals of this Talk...

- Provide a template for educators for building SSP expertise into students
- Demonstrate how much can be accomplished with student projects
- Solicit ideas for future projects and directions for MPT/SSP projects



Educational Conundrum

- Need to train more of our top people in SSP-related technologies
- The students need to build careers outside of SSP in order to survive professionally



William Brown Graduate Fellowship

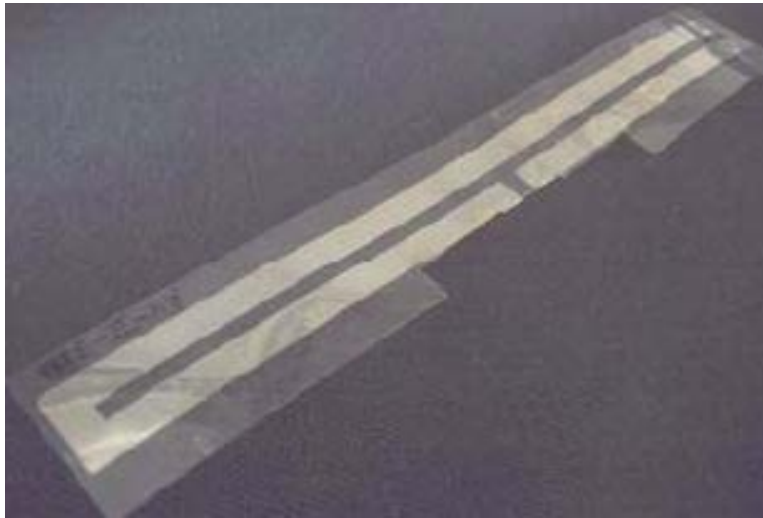


Senior Design SSP Demonstrator



Opportunity Research Scholars (ORS) Undergraduate Project

See-Through Rectenna



Use of Metal Ink-Jet Printer



Fall 2011 SatCom Project

- Group Projects (8+ teams, 4-5 members each)
- Challenging, Original Problem Statements
- Competitive Aspect of Grading
- Peer and Team Evaluations
- Web-based Project Reports
- Microwave Power Symposium at end of term
 - Presentation by Frank Little of Texas A&M
 - Hardware demonstration by undergraduates
 - Poster Session by graduate students



Online Summary of Projects

Satellite Communications & Navigation

home

online course

projects

Fall 2011 Space Solar Power

[Project Statement](#)

[Resource Page](#)



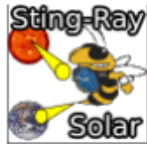
HELIOS



Sunwire



Star Tek Enterprises



Sting-Ray Solar



IRIS



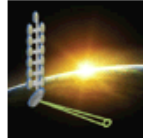
L.E.E.Co.



Death Raytheorp



The Van Allen Co.



Sun Beam

ECE 6390 Project Showcase



<http://www.propagation.gatech.edu/ECE6390/project/Fall2011/Project11.htm>

<http://www.propagation.gatech.edu/ECE6390/project/Projects.htm>



Student Knowledge Assessment

- Test content by period
 - 1: Astrodynamics
 - 2: Antennas & Propagation
 - 3: Telecommunications
- Significant increase in Test 1 & 2 performance (SSP expertise)
- No drop-off in Test 3 performance (non-SSP expertise)

Year	Test 1	Test 2	Test 3	# of students
2004	81.9	79.0	89.2	21
2005	85.7	67.8	84.2	22
2006	90.2	77.4	82.2	25
2007	88.4	83.4	82.5	40
2008	86.8	85.3	82.6	31
2009	84.7	87.5	90.4	44
2010	83.0	86.4	92.7	49
2004-2010	85.8	81.0	86.2	232
2011	88.8	90.7	85.2	42
change	+3.0	+9.8	-1.0	



Survey Results:

Project Mechanics

Statement	strongly agree	Partly agree	either way	partly disagree	strongly disagree
2. As a student, the end-of-term Microwave Power Transfer Symposium is a valuable experience and worth the time to attend.	7	7	1	0	0
3. The website format of the final report is preferable to a conventional final written report.	7	6	3	0	0
4. I would have preferred an individual project to the group project.	0	2	4	5	5
5. I do not like the competitive aspect of the group project.	0	3	6	5	2
6. The Space Solar Power group project made this class more work than the average graduate engineering course.	1	8	4	2	1



Survey Results:

Technical Content Interest

Statement	strongly agree	Partly agree	either way	partly disagree	strongly disagree
7. As a result of the Space Solar Power project, I have more interest and appreciation of RF engineering.	4	9	3	0	0
8. As a result of the Space Solar Power project, I have more interest and appreciation of solar cells and/or microelectronics.	1	8	5	2	0
9. As a result of the Space Solar Power project, I have more interest and appreciation of antennas and/or electromagnetic waves.	5	6	5	0	0
10. As a result of the Space Solar Power project, I have more interest and appreciation of system engineering concepts.	5	7	3	1	0



Survey Results:

Perception of Space Solar Power

Statement	strongly agree	Partly agree	either way	partly disagree	strongly disagree
1. This class was the first time that I had ever heard of the concept of space solar power.	9	1	1	0	5
11. By the end of this project, I have come to the conclusion that Space Solar Power is an impossible undertaking that will <i>never</i> result in an economical energy source for mankind.	1	4	3	4	4
12. As a result of this class and project, I plan to study space solar power more in the future.	0	6	5	3	2



Conclusions

- Demonstrated class assessment gains of +6.4% on content related to SSP
- Strong appreciation/interest developed for electromagnetics, RF engineering, systems engineering
- Students now literate in SSP issues, some inspired to continue study
- All content online: experience can be mimicked or duplicated



Lessons Learned

- Need a more focused project statement for any future SSP projects
- Peer evaluators do a better job collectively than I do in judging the efforts and correctness of projects

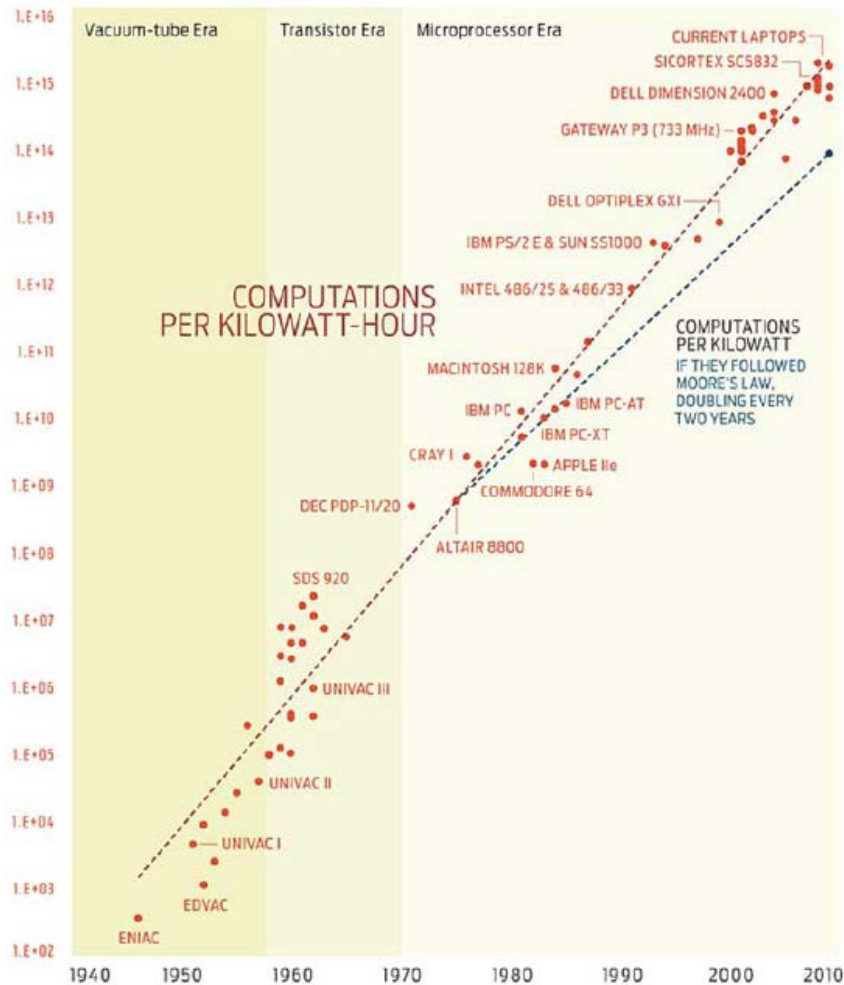


Example of Peer Evaluation

ECE 6390 Final Project: Peer Evaluation Sheet			
	TEAM X	TEAM X	TEAM X
	82	87	84
Summary Poster (out of 15)	13	15	14
Had a lot of writing a little hard to read but did have a lot of good information and the group had a very good in-depth discussion on the Microwave DC-RF hardware		The poster seemed professional and neat, effective, and of high quality.	Poster highlighted all the major design aspects. Well-designed and adequately presented by the group members.
Completeness (out of 15)	13	15	13
3 sections I would have liked to have seen a little more and that was about the orbits, Electronic resiliency and the budget/time line Microwave hardware section was a great strength		All of the issues that needed to be addressed by this report all seem to be accounted for.	Everything seems to be covered but in much greater detail than required. Negative marking for verbose descriptions.
Technical Correctness (out of 20)	15	17	13
I liked their section on PV cells and sheets and illustration that went along with it. Could tell they had people in the microwave profession had one of the best microwave sections and the hardware used than any other group.		The transmitter power density seems a little too high for comfort since we are transmitting to habited areas. Micrometeorites are not considered for degradation of solar cells. I am unsure that the 418MHz band is available for use with this application.	This design appears to be technically sound but the end-to-end efficiency calculations are very optimistic.
Research & References (out of 15)	15	14	13
They had very good research especially in microwave energy and components sections		Citations seem scattered and between each page they do not seem to conform to one method of citation so it is difficult to determine which content was used for the citations. Perhaps superscripts would have been better, however everything seems to have been cited that needs to be.	All references listed together at the end of page, not as footnotes. Very hard to find the source for a particular listing on any given page.
Professional Content (out of 15)	13	12	15
Was a little hard to figure what orbit they choose since both LEO and GEO are mentioned and Satellite communication was a little short. Very good microwave hardware design sections!		The website looks somewhat low-end. Sort of the style from about the late 1990s and could look a little more modern, but the layout and content organization seems appropriate and professional.	All the design aspects are well presented with nice illustrations. Website is easy to navigate.
Feasibility (out of 20)	13	14	16
It seems they underestimated the cost of each satellites. Not sure how they get to \$0.01/KWh. Budget not complete enough for me to see this number. Looks like they need 230 to get to this number and numbers for just 16 are given!		The size of the rectenna array antenna seems a little unlikely (5.3km). The lifetime of the satellite (due to solar cell degradation) seems far fetched. The rest of the design seems feasible with the assumptions listed.	Modular construction at LEO as proposed in this design with 300 launches required per satellite is not feasible at this point of time but may be possible in the future.



Moore's Law in a New Light

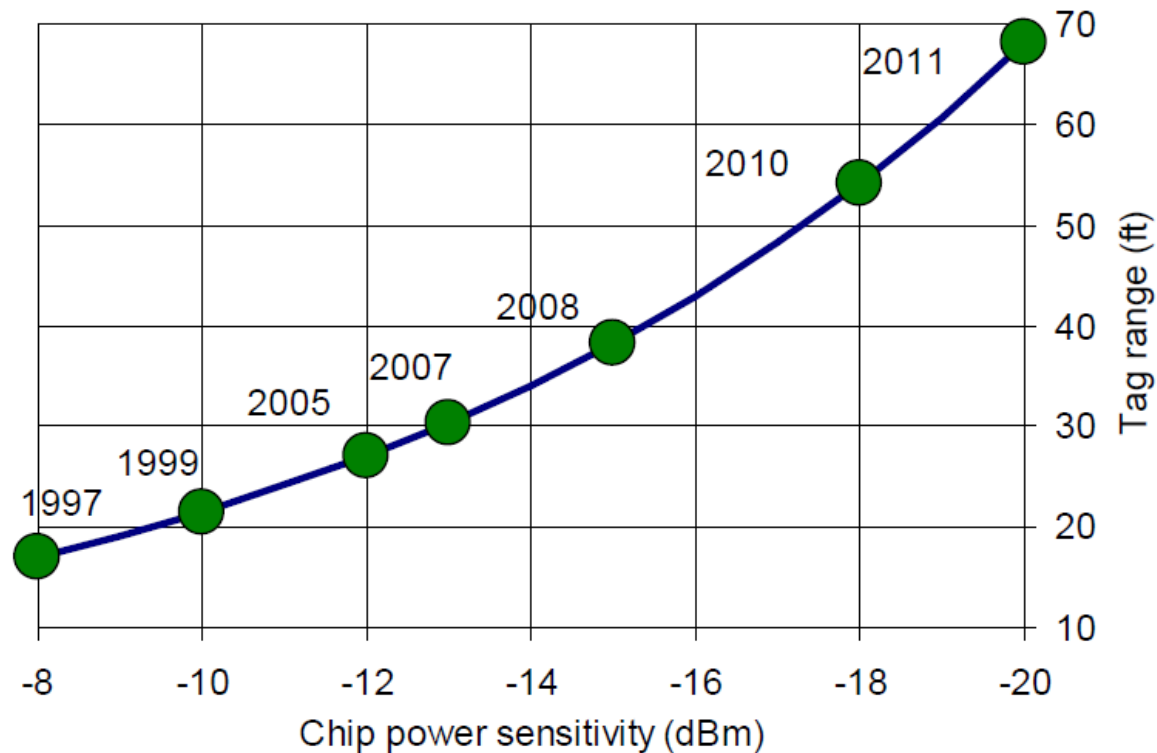


- Basic Trend: comp. power doubles < 2 years
 - ...in Operations/Joule
 - ...for the last 70 years!
 - ...when accounting for *all* chip gains
- Does not say anything about speed

*J.G. Koomey, *IEEE Spectrum*, March 2010



Gains for Passive Communications



**Figure 2 – Tag read range vs. chip sensitivity
(4 W EIRP, free space, 915 MHz, 2 dBi matched tag).**

P. Nikitin, KVS Rao, S. Lam, “UHF RFID Tag Characterization: Overview And State-of-the-Art”. AMTA Conference, Seattle, Oct 2012.

