

Future RF Market Opportunities for GaN

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Panel Session 8:00 -10:00 AM

STRATEGYANALYTICS



Agenda



- Introduction of Strategy Analytics
- Why is GaN Interesting?
- Production Markets
 - Military
 - Commercial
- Market Estimates
- Trends
- Challenges

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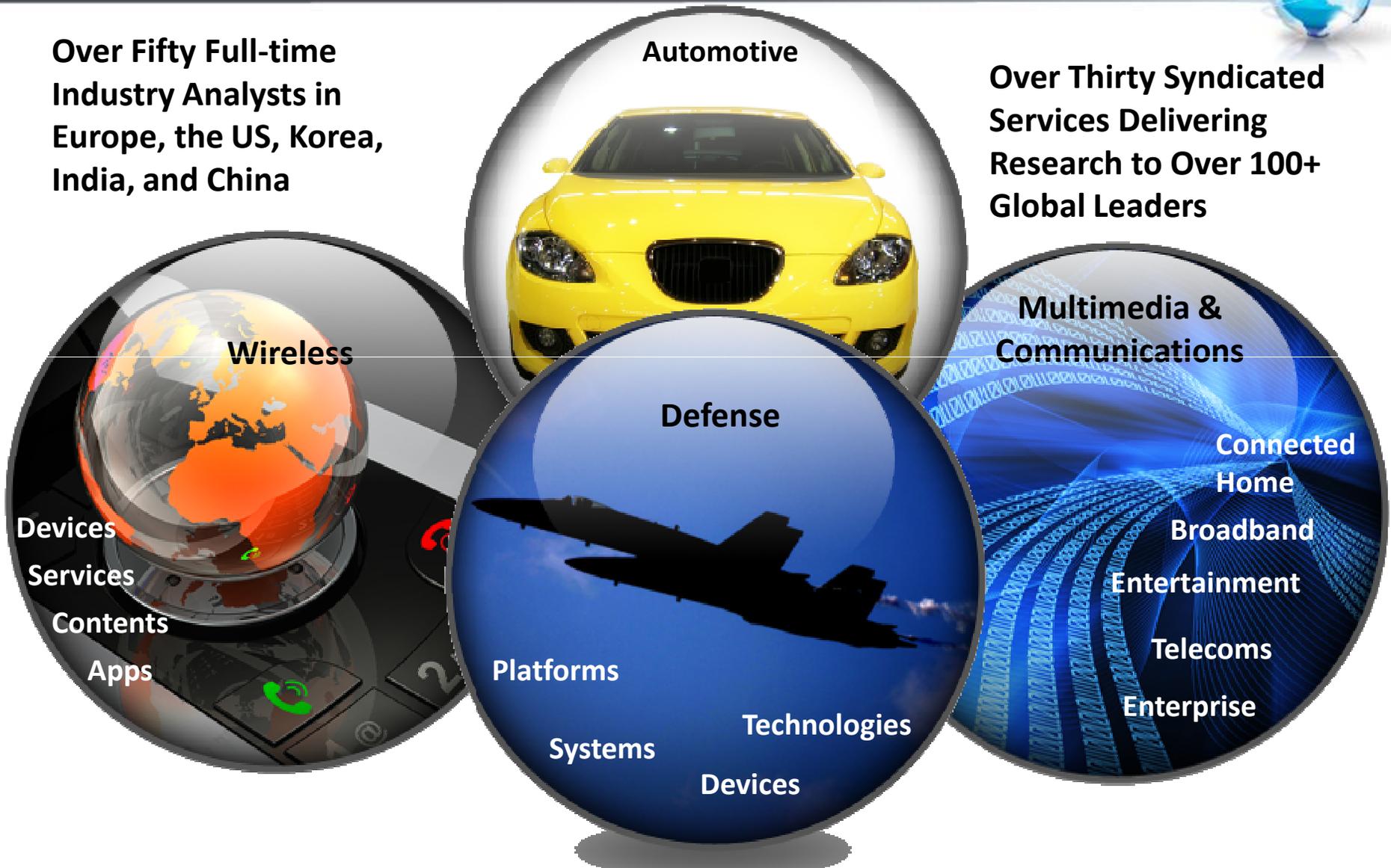




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GaN Characteristics versus Other Technologies

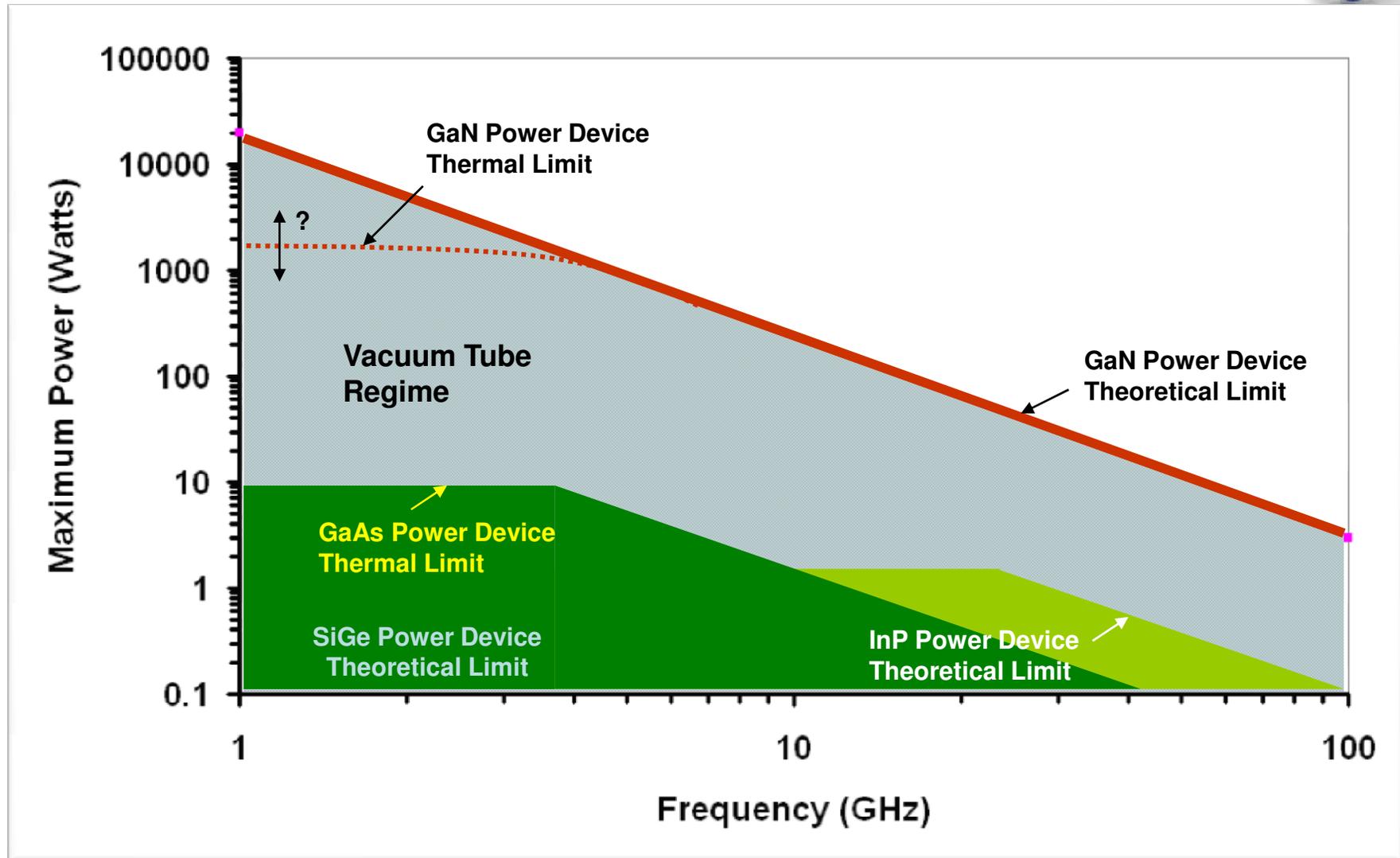


Metric	Si	GaAs	InP	SiGe	SiC	GaN
Lattice constant (Å)	5.4	5.7	5.9	5.5	3.1	3.2
Saturation velocity (cm/s)	1×10^7	0.8×10^7	2.2×10^7	---	2×10^7	2.5×10^7
e-mobility (cm ² /Vs)	1350	8000	10000	3000	900	1500
Eg bandgap (eV)	1.1	1.4	1.3	0.7-1.1	3.3 (4H)	3.4
Ft (GHz) FET	20	150	300	50	20	150
Power density (W/mm)	0.2	0.5	---	0.3	10	>30
Thermal conductivity (W/cmK)	1.5	0.5	---	---	4.9	~2.0

Source: GaAs, *GaN Microelectronics Market Update 2009-2014*, published Apr'10

- Wide bandgap (3.4eV), high breakdown voltage, extremely high power density and high gain
- Higher output impedance makes matching and combining easier
- Higher and broader frequency coverage than other “power” technologies

RF Power Enabling Technologies





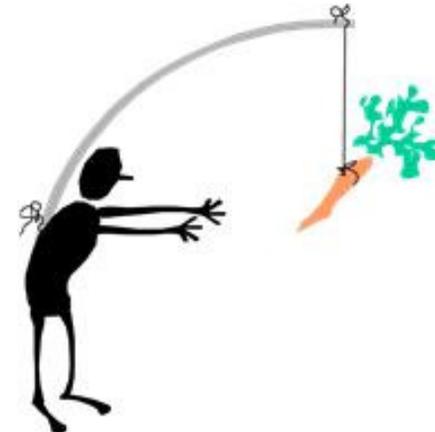
Production Military Markets for GaN

- **Electronic warfare**
 - Uses broadband and high-power microwave emission
 - Disrupt and jam RF signals used to detonate IEDs
- **AESA Radar**
 - Arrays rely on hundreds or thousands of T/R modules that can be phase shifted to form and steer the beam
 - So many modules place a premium on size, weight, power efficiency and high power performance
- **Tactical Radio Communications**
 - “Network-centric” battle philosophy demands agile, broadband communications channels
 - Radios may have to operate over a frequency range of 30-3000 MHz at power levels up to 100W, while accommodating portable, manpack and vehicle mount form factors

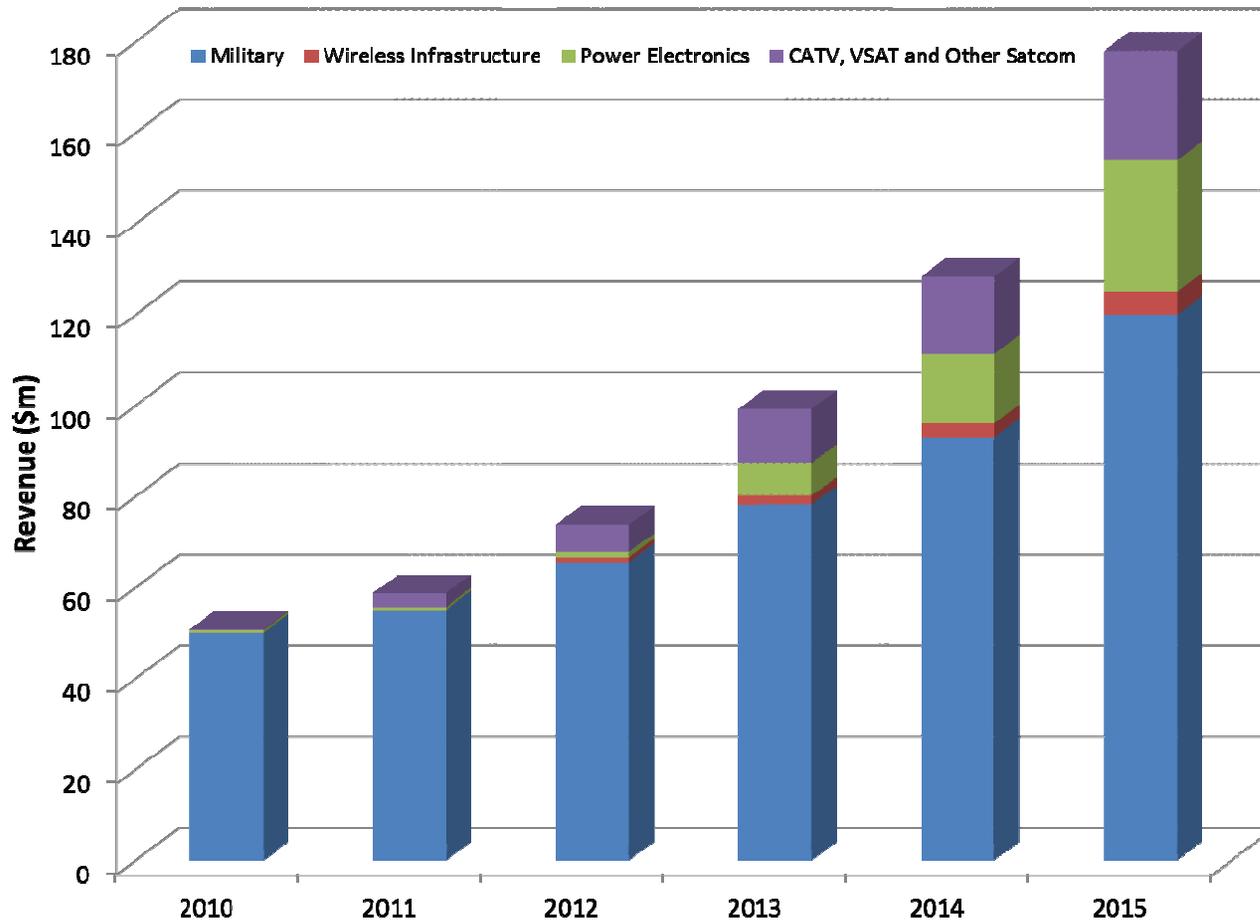
Production Commercial Markets for GaN



- Results are not nearly as promising
- Initial targets have not materialized as expected
 - **Automotive:** long industry design cycles, SiC performance and cost have limited GaN market share
 - **Infrastructure:** WiMAX with higher frequency, green-field implementations was seen as the perfect vehicle, but WiMAX deployment has faltered and LDMOS has proven *very* resilient
- ...But the motivation remains!
 - CATV
 - Equivalent performance at lower bias (OPEX)
 - Better performance at same bias (CAPEX)
 - Satellite
 - *Complementary* to TWTAs
 - High Power Electronics
 - Manufacturing high volumes at low cost on silicon substrates

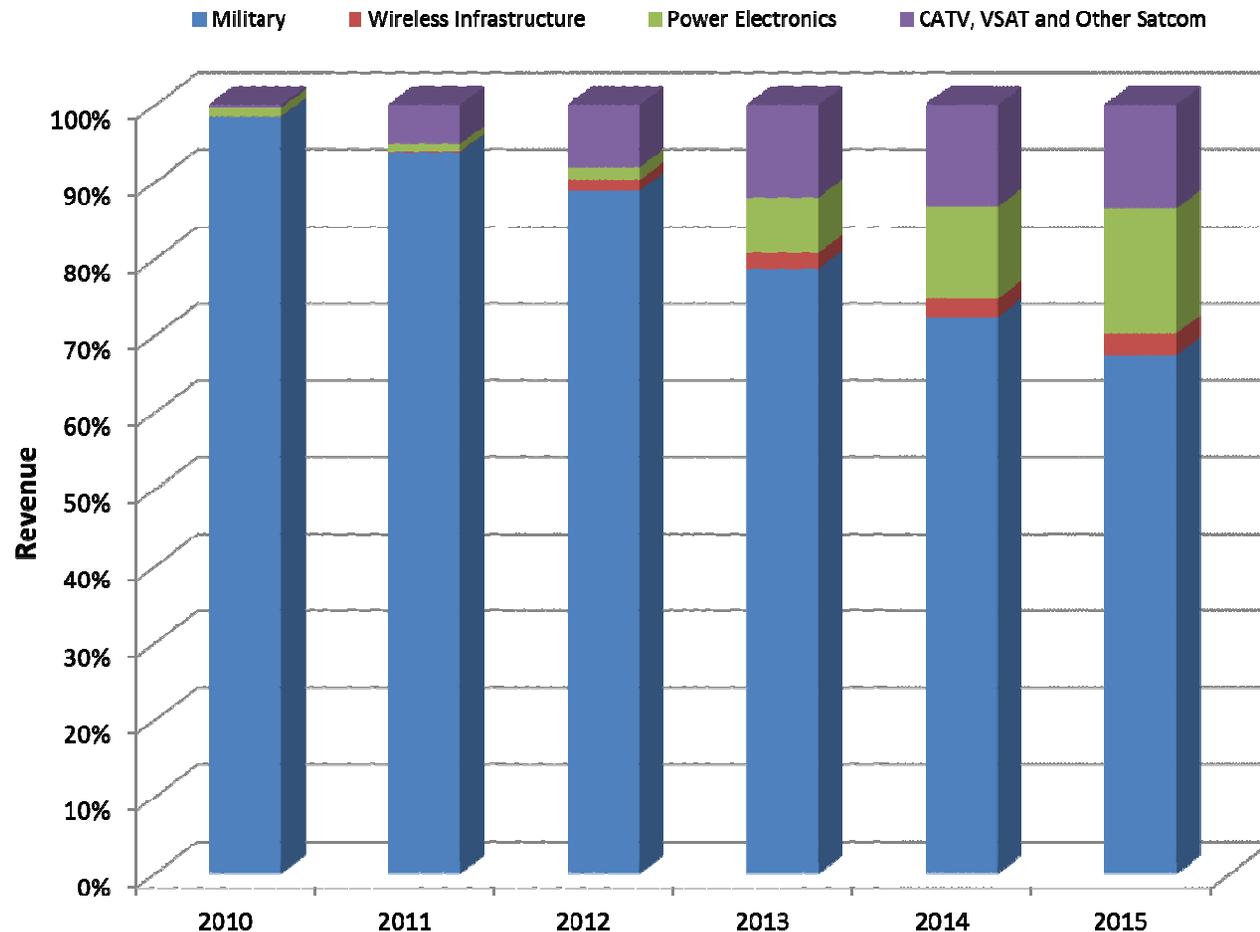


GaN Market Estimate



- Market Value is ~\$180M in 2015
- 28% CAAGR 2010-2015

GaN Market Segmentation



- Military applications still account for ~67% of market in 2015
- Both CATV and HPE segments have CAAGR >>100%



Trends that *Could* Enable GaN Adoption

- OPEX reduction has become **very** important
 - Higher PA efficiency means less power consumption
 - While this is green and good for the environment, it also improves the bottom line
 - Higher frequency capability enables more compact antennas and electronics
 - Siting for commercial applications is easier & cheaper
 - Allows for higher “capability/form factor” ratios in military applications
 - Ability to withstand higher operating temperatures reduces need for cooling
- Increasing capability to the war fighter
 - Broadband frequency capability enables multi-band radios
 - “Network-centric” battlefield philosophies require networking legacy radios from different branches of the military, using several different frequency bands
 - Higher output power capability of GaN devices increases system sophistication
 - Longer threat detection/neutralization for radars and jammers
 - AESA radars can either be smaller & lighter for equivalent performance or higher performance for equivalent size and weight



Challenges for GaN

- **Cost, cost, cost**
 - Pricing for LDMOS has reached ~\$0.20's/W
 - GaN is able to command ~15-30% price premium over GaAs in CATV applications
 - Does this reflect true costs and is this sustainable?
- **Silicon vs. SiC for substrate**
 - Silicon appears attractive because of cost and established infrastructure
 - How do you solve the manufacturing challenges?
 - Does this limit potential market applications
- **Packaging**
 - Military OEMs are comfortable with bare die, but the commercial model relies on packaged parts
 - How much of the performance advantage do we lose with the packaging?
- **“Small Cells”**
 - What does the trend toward lower power cells mean for GaN adoption in infrastructure?