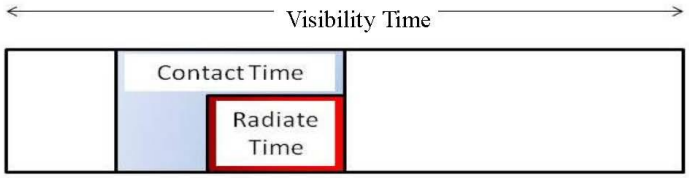
Methodology – Theoretical Bases and Assumptions (3/3)

- **Contact Time**
  - *Based on statistical records averaged for one year for the AFSCN sites and estimated for non-AFSCN sites*
  - *Actual radiation time is less than visibility time as depicted in the figure below*



  - *Note that publicly available ITU registration data may be used to estimate visibility time, but does not indicate actual radiation time*
  - *There is sometimes flexibility in contact time scheduling; many times there is not flexibility*

2220

12

Methodology – Model Uncertainties

- **Major factors constraining utility of analysis results and conclusions**
  - *Uncertainty of applicability of ITM model to urban propagation*
  - *Uncertainty inherent in use of ITM model without ground truth*
  - *Unknown impact of input variables on ITM model outputs*
- **Minor factors**
  - *Underestimation of SATOPS Radio Frequency Interference (RFI) due to distribution of radiate time*
  - *Underestimation of SATOPS RFI due to not accounting for elevation angle to first path obstruction*
- **Unknown factors**
  - *Possibly inadequate terrain data resolution*
  - *Possible electromagnetic environment factors to which ITM is not sensitive*
  - *Uncertainty in the effect of receiver site constraints*
  - *Changes in the terrain*

2221

13

Methodology – Impacts of Model Uncertainties

- **Effects of propagation loss uncertainties upon Power and Threshold Exceedance Plots**
  - *Due to change in propagation path electrical parameters (soil conductivity and dielectric constant and surface refraction)*
  - *Due to regional characteristics (climate types and terrain types)*
  - *Due to variations in time (diurnal and seasonal)*
  - *Due to MW station receiver siting (constrained to achieve exposure to handsets while minimizing exposure to interference)*
  - *Due to limited terrain database resolution*
- **Effects of SATOPS modeling enhancements upon power and Threshold Exceedance Plots**
  - *Due to antenna pattern approximation (due to use of envelope mask)*
  - *Due to variation in radiate start/stop times*
  - *Due to use of elevation angle to first obstacle*

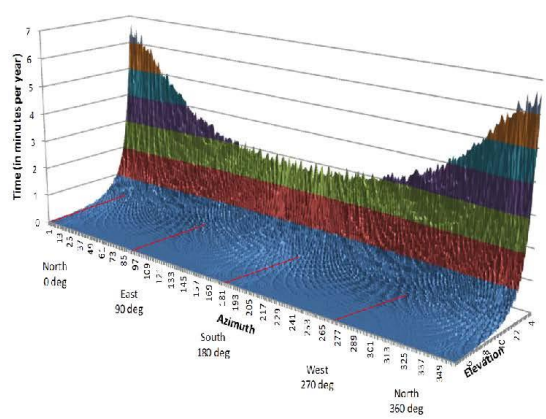
2222

14

Methodology

Visibility Time as a Function of Ground Antenna Pointing Angles

- **The figure represents an example visibility for a single non-geostationary satellite with one frequency uplink accumulated over one year in 1°x 1° Az/El cells**
- **Calculations include the number of minutes per year that a given antenna points in a given azimuth and elevation in supporting one single non-geostationary satellite**
- **Illustrative of the type of data that is combined for multiple satellites in arriving at a composite profile for the earth station's radiation over the year**
- **Note the antenna only points in any given direction a small percentage of the time**



2223

15

Methodology - Power Contour Plots

- **Power radiated from each of the Government sites along with other computational details are presented in Appendix B**
- **These calculations use 1 kW transmitter power for AFSCN sites for the analysis**
  - *The AFSCN power actually varies from 500 W to ~ 7kW, within the US*
  - *A few maximum power cases are included for comparison*
- **The contours are calculated using the NTIA Irregular Terrain Model (ITM) with the GLOBE Terrain Data Base for propagation loss and are accurate to 1 and 5 km grid spacing as labeled**
  - *1 or 5 km grid spacing, as limited by the GLOBE data base, adds considerable uncertainty because natural terrain features can be greatly varied over these distances*
- **This model does not take into account vegetation or artificial structures so a 20 dB attenuation factor on the radiated signal was also added to some of the analyses cases**

2224

16

Methodology

Mobile Wireless Long Term Evolution (LTE) System Threshold Exceedance

- **The received power level was calculated and compared to the LTE threshold of -137.4 dBW (1dB desense level) for each potential LTE base station site and at each antenna pointing angle**
  - *The percentage non-exceedance time is that which the MW base stations can operate without RFI given the stated LTE threshold*
  - *1 dB desense level is used as the interference criterion for the LTE receiver; it is the level at which the apparent receiver noise floor is increased by 1 dB, thereby reducing the effective sensitivity by 1 dB*
- **The center color of the plot(s) (i.e. nearest to the ground station) represents the minimum value of threshold non-exceedance which is the complement of the site radiation percentage time**
- **This study uses aggregated statistics of radiation to spacecraft over a given band for the past year**

2225

17

Study Results

- **Using data characterizing typical SATOPS at the selected sites, and applying propagation modeling as described, contour plots in Appendix A were generated**
  - *Power Contour Plots in the relative vicinity of the sites as a function of azimuth and distance*
  - *Threshold Exceedance Plots of the probability that the predicted SATOPS signal level at various points of azimuth and distance does not exceed the threshold interference criterion*
- **Results are subject to uncertainties of the modeling process further elaborated in Appendix B**

2226

18

Summary

- **SATOPS information requested by the CSMAC WG3 to assess Government and commercial sharing of the 1755-1850 MHz band is provided**
- **A methodology for estimating power contours over geographic areas is presented**
- **Limitations of models to simulate power profiles are described**
- **Results are based on general usage but are not actual operational scenarios for Government SATOPS ground sites**
- **This study is not intended to support any derivation of requirements**
- **Impacts to future commercial operations can only be estimated at this time**
- **Still need to assess actual ground site parameters for potential impacts**
- **Regulatory provisions should allow for potential changes in Government mission requirements including the possibility of greater satellite contact times, higher power levels at existing sites and the addition of new sites**

2227

19

Study Reference

1. Satellite Orbit Analysis Program (SOAP), The Aerospace Corporation, OTR-2013 0314155423, 2013

2. "Integrated Terrain Model" by NTIA/ITS, see: http://www.its.bldrdoc.gov/resources/radio-propagation-software/itm/itm.aspx

3. The Global Land One-km Base Elevation Project (GLOBE) Elevation Database, National Geophysical Data Center, NOAA; available online at: http://www.ngdc.noaa.gov/mgg/topo/globe.html

4. Commerce Spectrum Management Advisory Committee, Final Report, Working Group 1-1695-1710 MHz Meteorological-Satellite, dated 1/22/2013, downloaded from: http://www.ntia.doc.gov/other-publication/2013/csmac-wg-1-final-report-v2

5. "Antenna Models for Electromagnetic Compatibility Analyses," NTIATM-13-489, National Telecommunication and Information Administration Technical Memorandum, October 2012

6. "Government Satellite Control Overview", 2 Oct 12 [Government submittal 1 to CSMAC WG3]

7. NTIA Manual of Regulation and Procedures for Federal Radio Frequency Management, May 2012

8. "Commerce Spectrum Management Advisory Committee (CSMAC) Working Group (WG) 3 Phase II Study Summary" Aerospace Report No. TOR-2013 00257, May 29, 2013

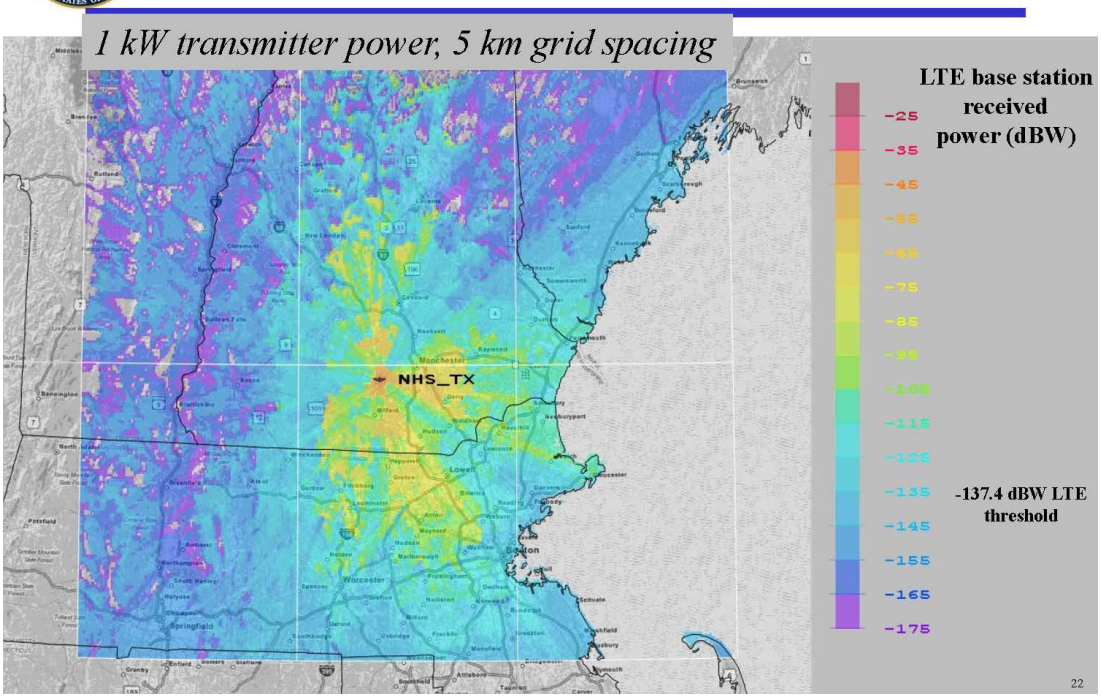
Charts 2 through 83 were reprinted with permission of the Aerospace Corporation

Appendix A: Study Results

Type of Plot	Grid (km)	Site					
		NHS	VTS	HTS	BPTF	FB/AK	LP/CA
Power Contour	5	22-23	36-37	48-49, 51	59-60	67-68	70-71
Power Contour with 20 dB attenuation	5	24-25	38-39	50, 52	61-62	67-68	72-73
LTE Threshold Exceedance 1755-1780 MHz	5	26	42	53	63		
LTE Threshold Exceedance 1755-1780 MHz	1				65	69	
LTE Threshold Exceedance 1755-1780 MHz, with 20 dB attenuation	1	27	43	54	64,66	69	
LTE Threshold Exceedance 1780-1805 MHz	5	28	44	55			74
LTE Threshold Exceedance 1780-1805 MHz	1						75
LTE Threshold Exceedance 1780-1805 MHz, with 20 dB attenuation	1	29	45	56			
LTE Threshold Exceedance 1805-1850 MHz	5	30	46	57			
LTE Threshold Exceedance 1805-1850 MHz, with 20 dB attenuation	1	31	47	58			
Power Contour (radiating at 5.02 kW)	5		40				
Power Contour (radiating at 5.02 kW) with 20 dB attenuation	5		41				
Power Contour (radiating at 7.244 kW)	5	32					
Power Contour (radiating at 7.244 kW) with 20 dB attenuation	5	33					
LTE Threshold Exceedance 1755-1780 MHz (radiating at 7.244 kW)	5	34					
LTE Threshold Exceedance 1755-1780 MHz (with 10 dB standard deviation applied to propagation loss)	5	35					

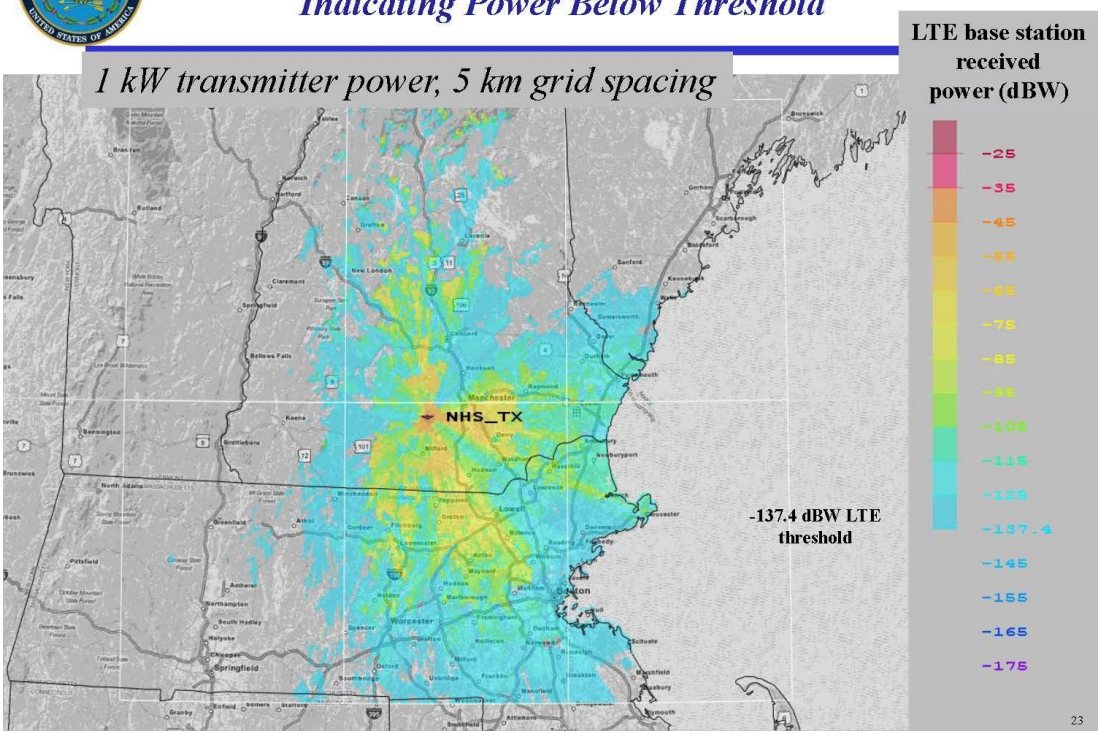
*Unless otherwise stated in the Table, charts reflect transmit power of 1 kW except BP, MD power of 300 W

NHS Power Contours



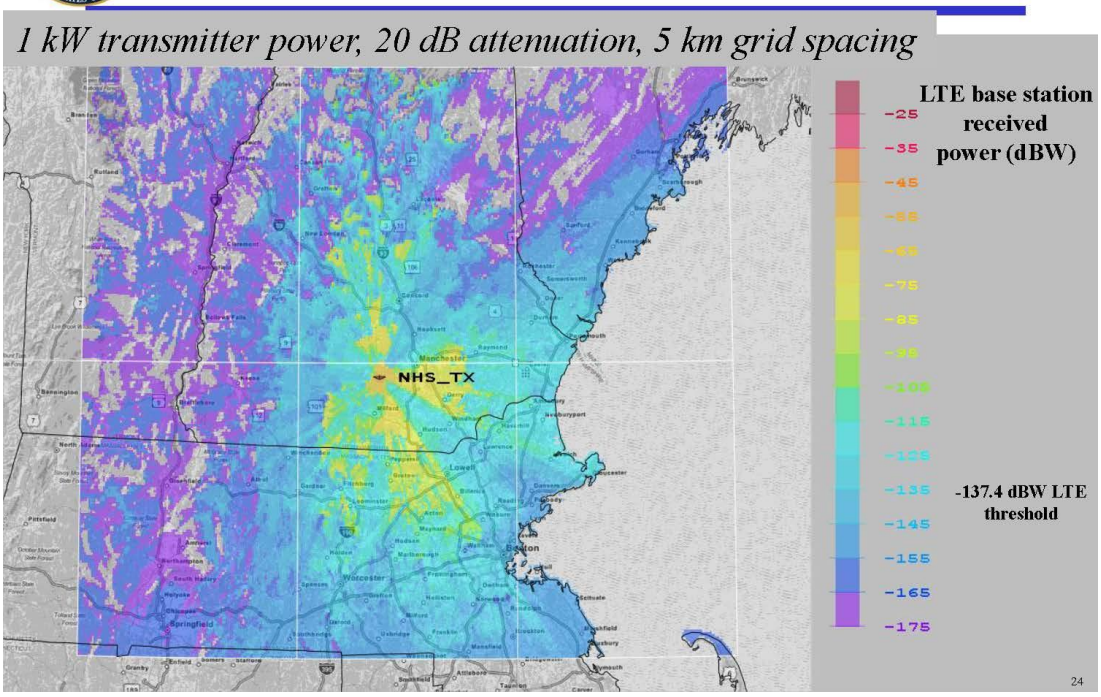
2230

NHS Radiated Power With Natural Terrain in Grey Indicating Power Below Threshold



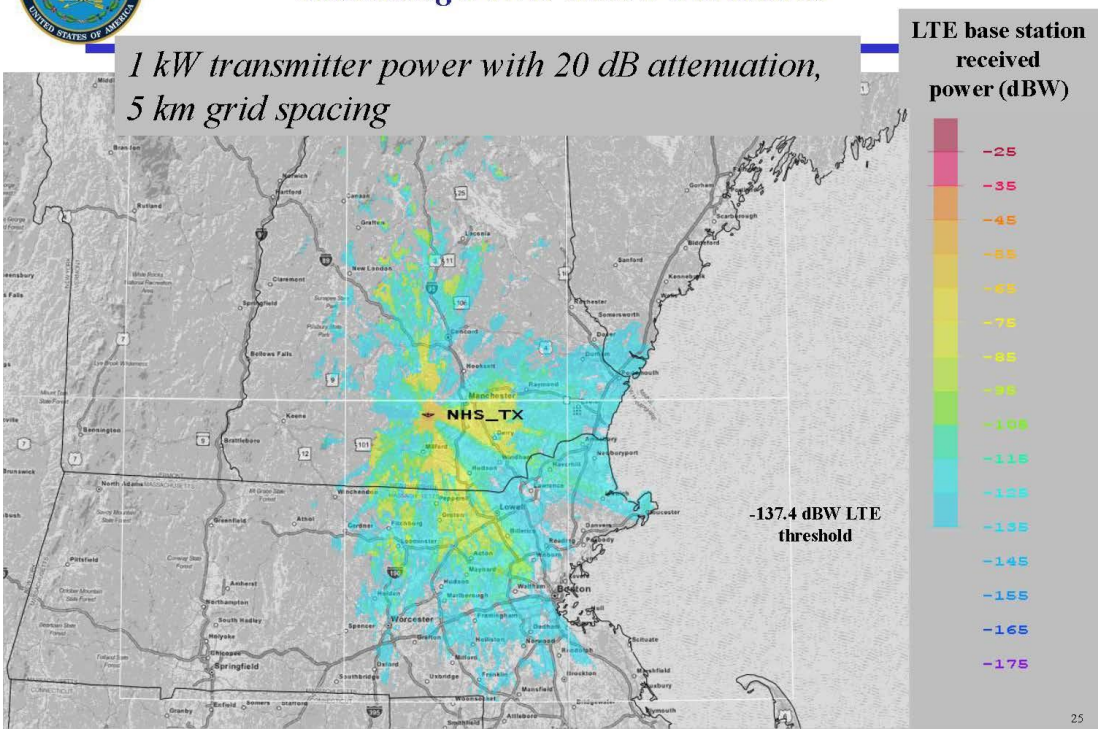
2231

NHS Power Contours



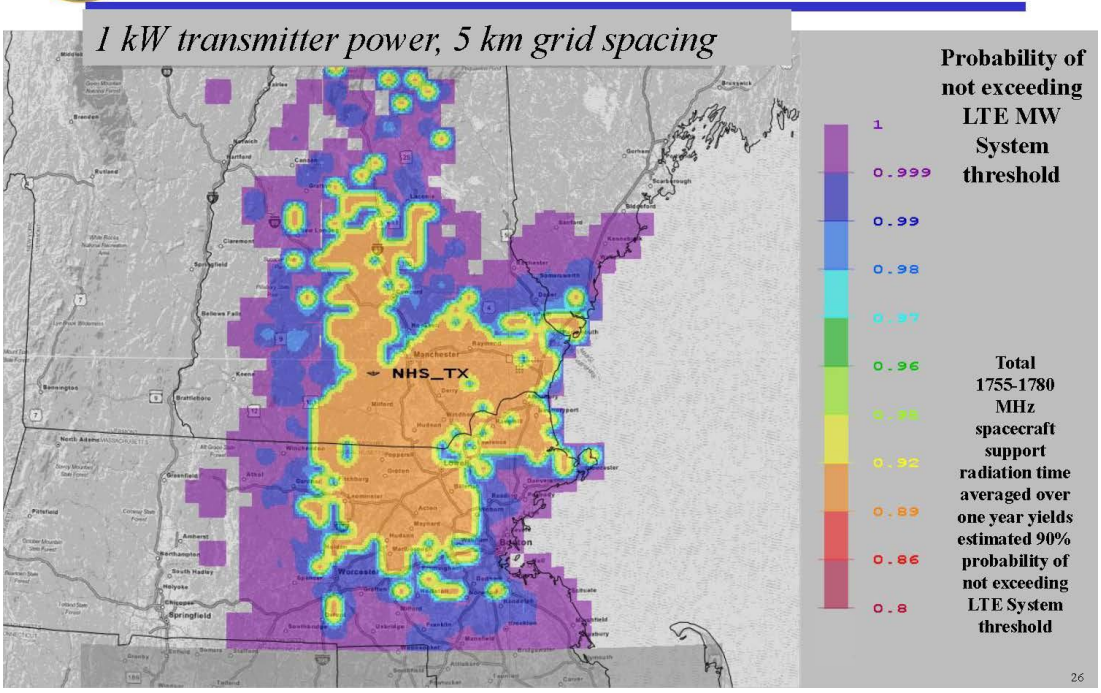
2232

NHS Radiated Power With Natural Terrain in Grey Indicating Power Below Threshold



2233

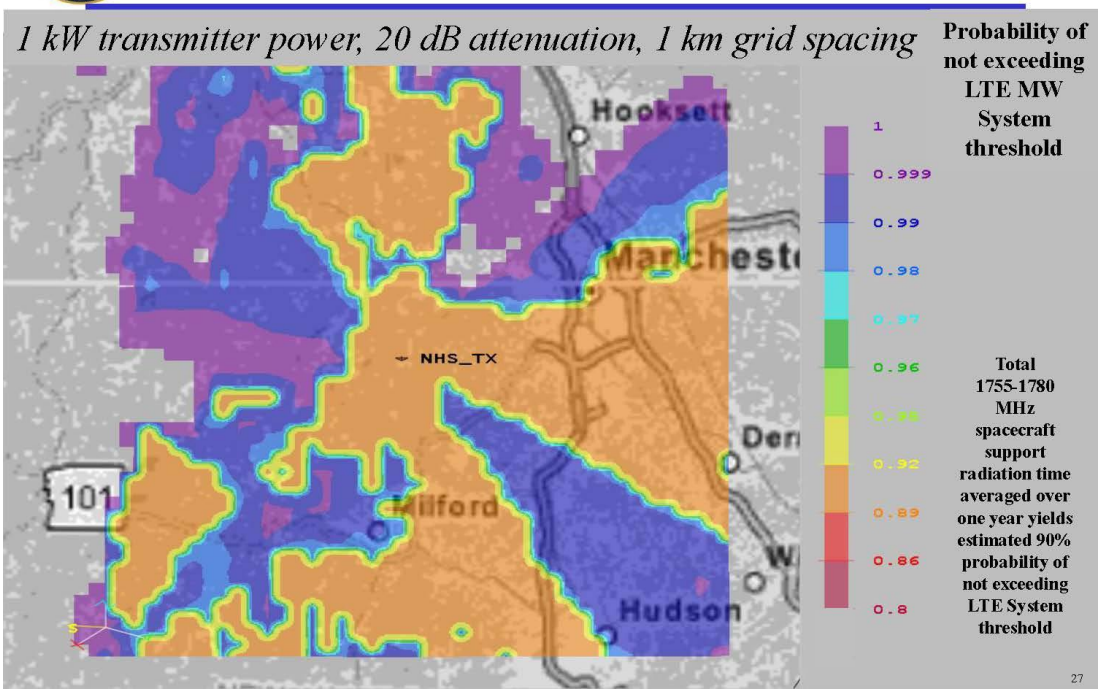
NHS LTE System Threshold Exceedance, 1755-1780 MHz



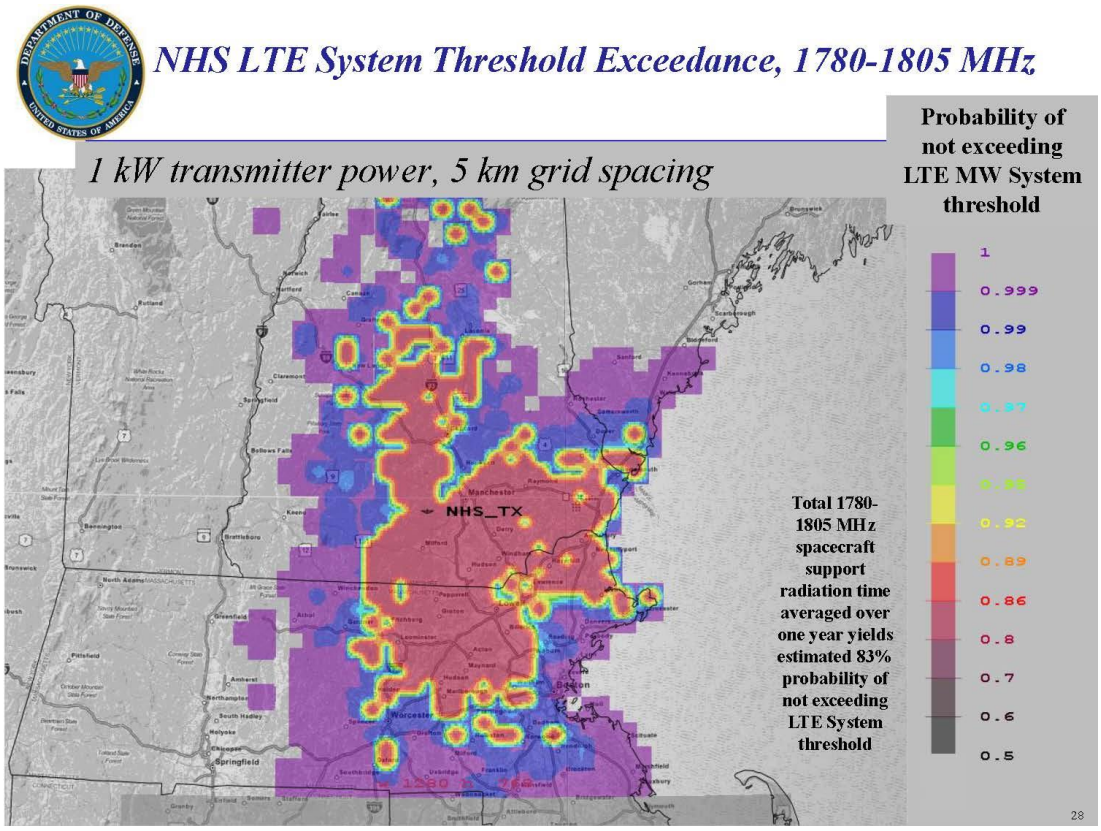
2234

NHS LTE System Threshold Exceedance, 1755-1780 MHz

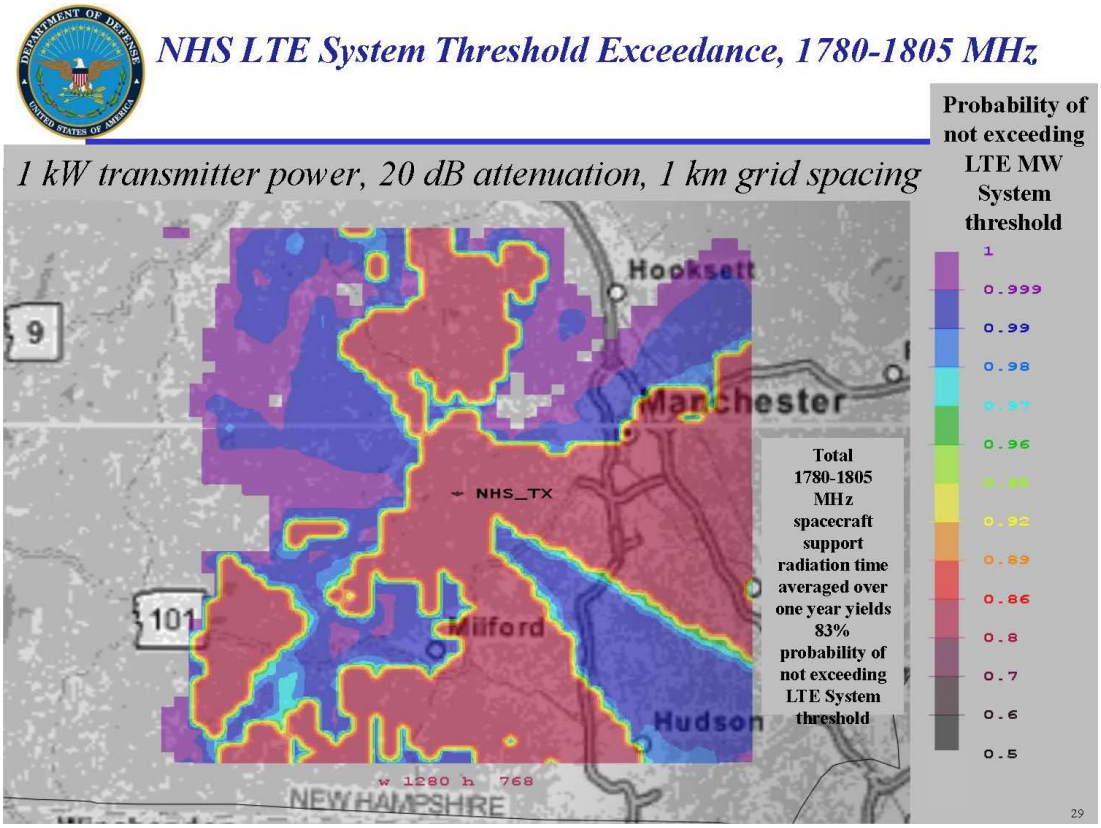
Plots of this type are magnified by a factor of five compared with the previous plots



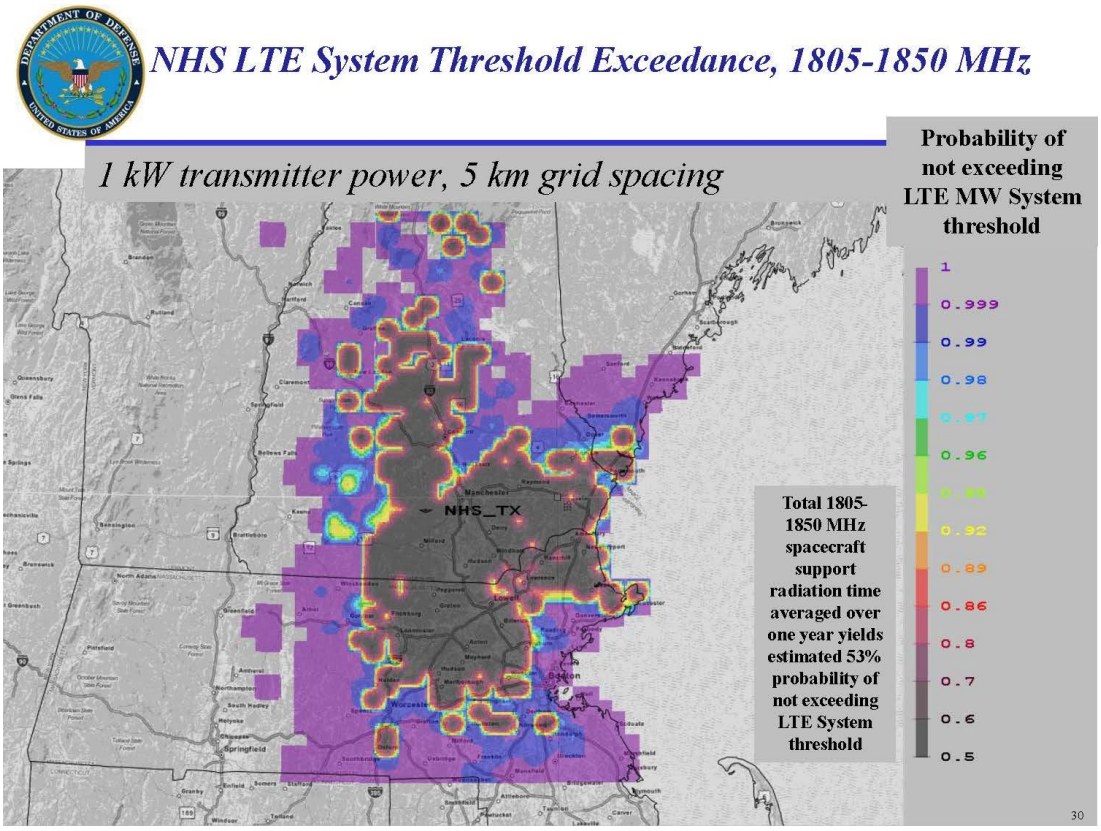
2235


NHS LTE System Threshold Exceedance, 1780-1805 MHz
1 kW transmitter power, 5 km grid spacing
Probability of not exceeding LTE MW System threshold
1
0.999
0.99
0.98
0.97
0.96
0.95
0.92
0.89
0.86
0.8
0.7
0.6
0.5
NHS_TX
Total 1780-1805 MHz spacecraft support radiation time averaged over one year yields estimated 83% probability of not exceeding LTE System threshold
28

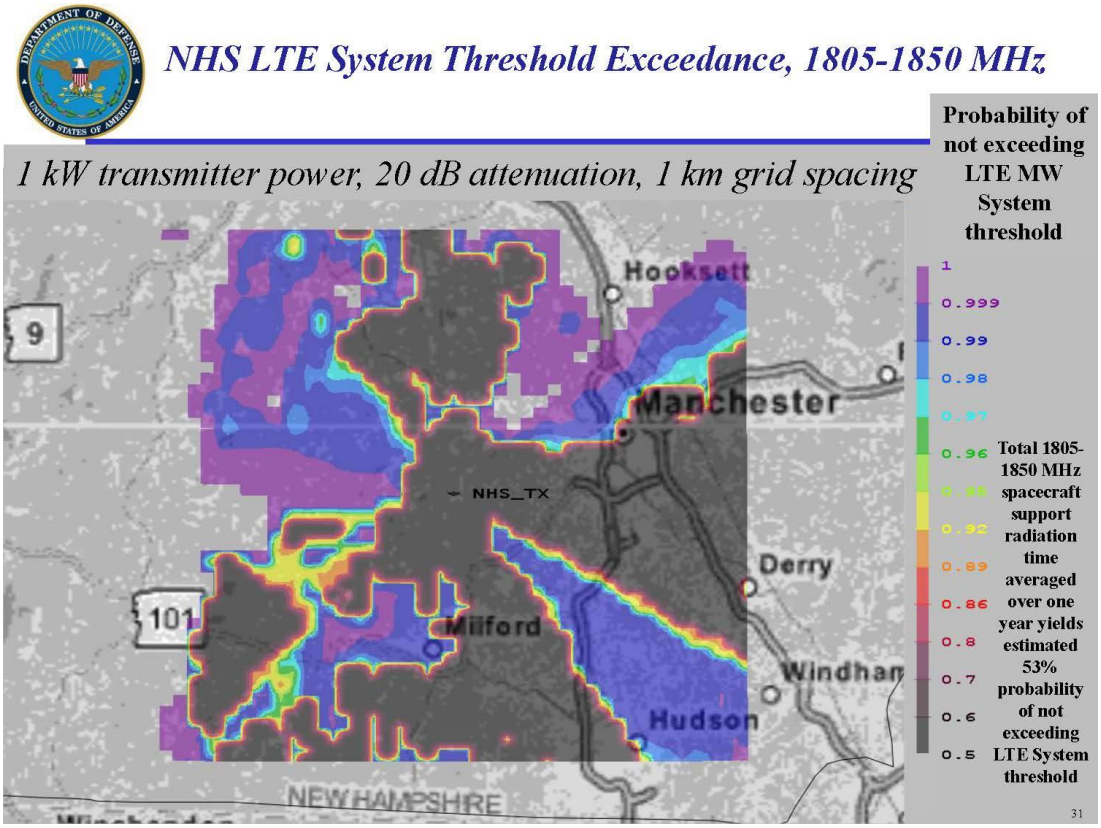
2236


NHS LTE System Threshold Exceedance, 1780-1805 MHz
1 kW transmitter power, 20 dB attenuation, 1 km grid spacing
Probability of not exceeding LTE MW System threshold
1
0.999
0.99
0.98
0.97
0.96
0.95
0.92
0.89
0.86
0.8
0.7
0.6
0.5
Hooksett
Manchester
NHS_TX
Milford
Hudson
9
101
w 1280 h 768
NEW HAMPSHIRE
Total 1780-1805 MHz spacecraft support radiation time averaged over one year yields 83% probability of not exceeding LTE System threshold
29

2237

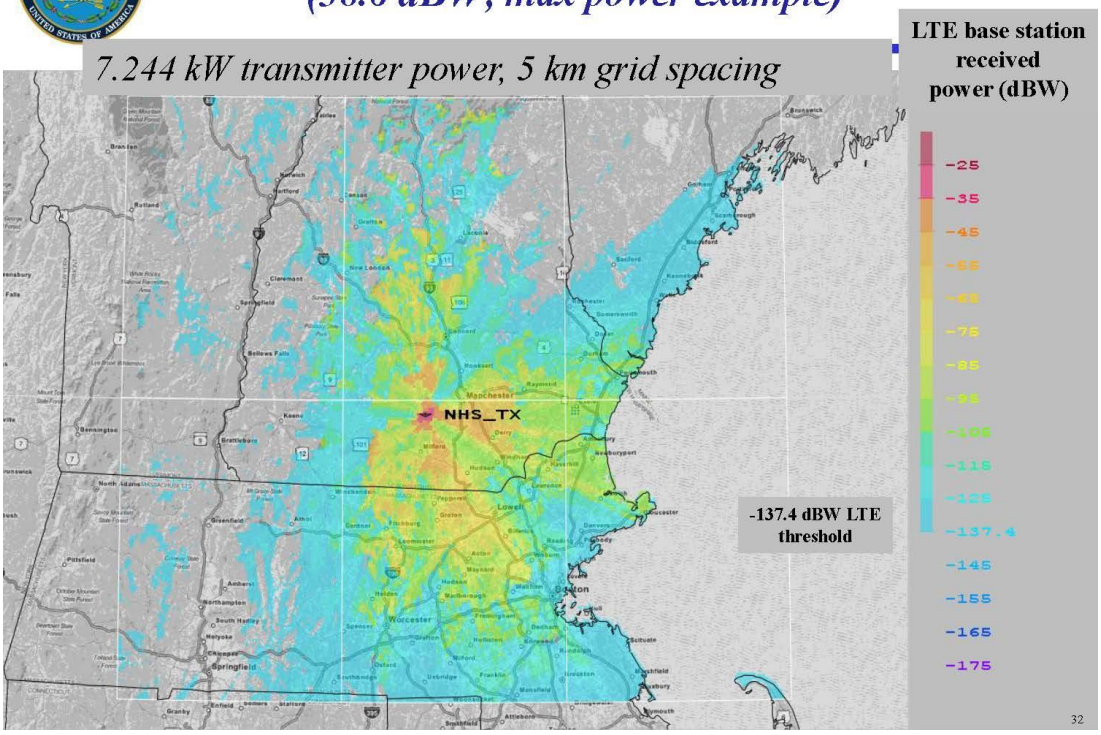

NHS LTE System Threshold Exceedance, 1805-1850 MHz
1 kW transmitter power, 5 km grid spacing
Probability of not exceeding LTE MW System threshold
1
0.999
0.99
0.98
0.97
0.96
0.95
0.92
0.89
0.86
0.8
0.7
0.6
0.5
NHS_TX
Total 1805-1850 MHz spacecraft support radiation time averaged over one year yields estimated 53% probability of not exceeding LTE System threshold
30

2238


NHS LTE System Threshold Exceedance, 1805-1850 MHz
1 kW transmitter power, 20 dB attenuation, 1 km grid spacing
Probability of not exceeding LTE MW System threshold
1
0.999
0.99
0.98
0.97
0.96
0.95
0.92
0.89
0.86
0.8
0.7
0.6
0.5
Total 1805-1850 MHz spacecraft support radiation time averaged over one year yields estimated 53% probability of not exceeding LTE System threshold
Hooksett
Manchester
NHS_TX
Derry
Milford
Windhan
Hudson
NEW HAMPSHIRE
9
101
31

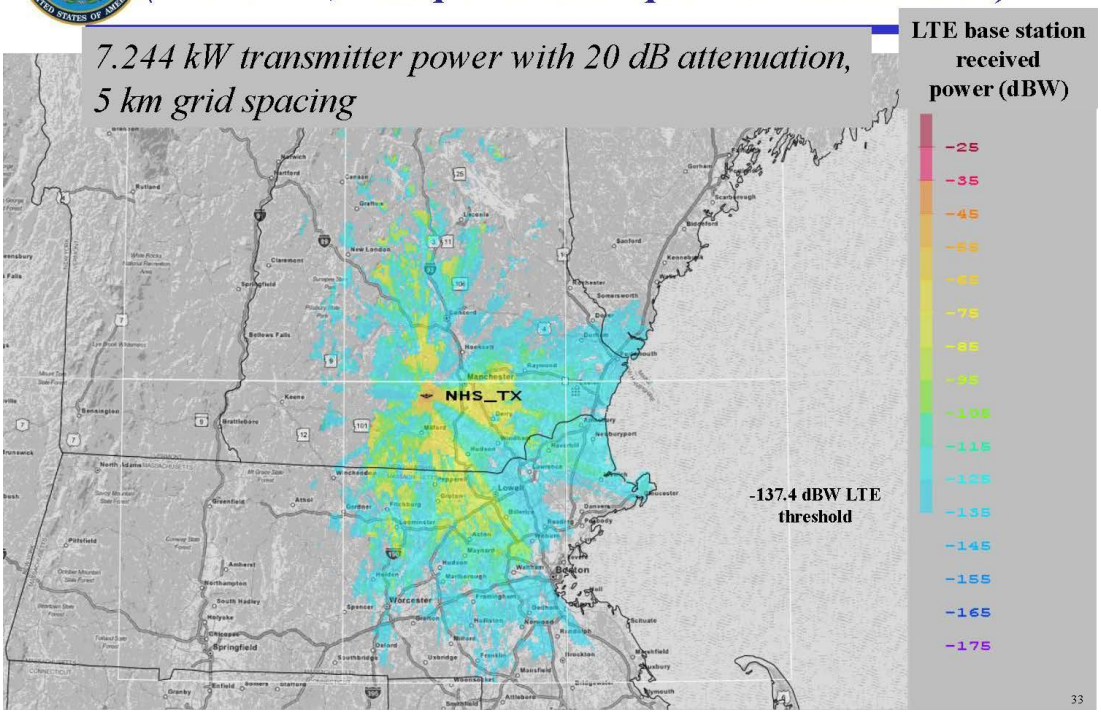
2239

NHS Radiated Power
(38.6 dBW, max power example)

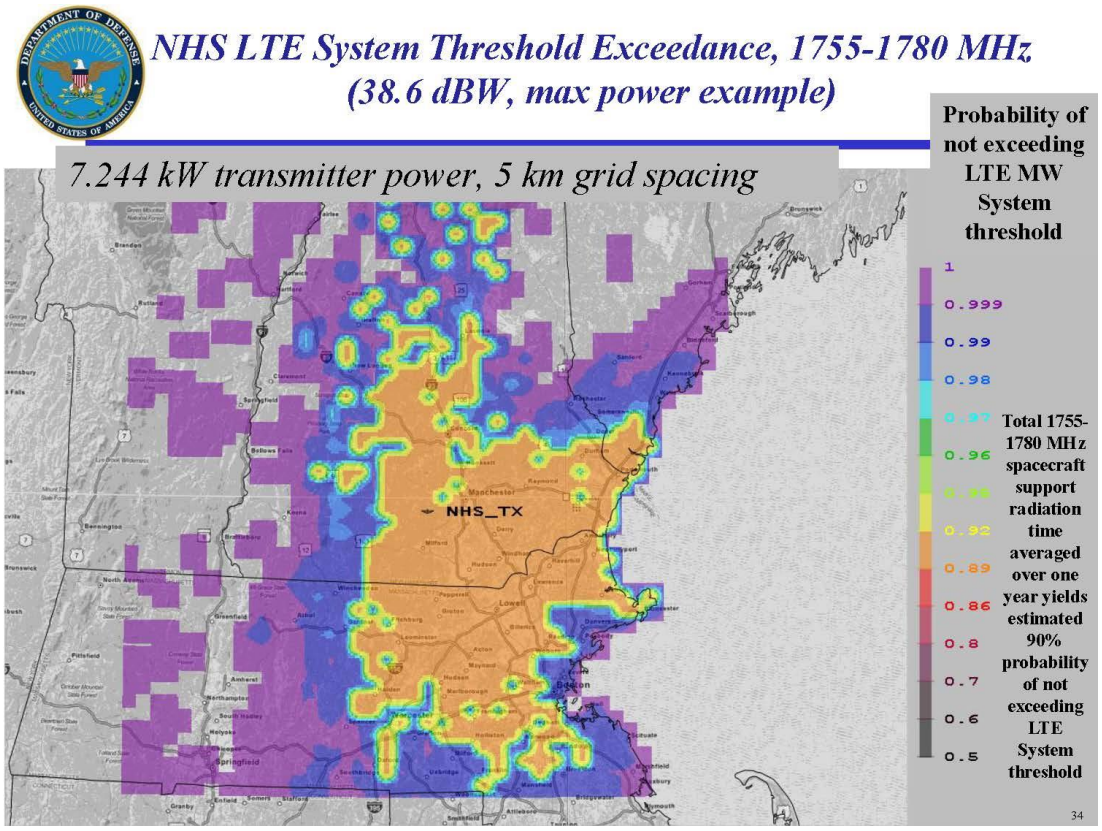


2240

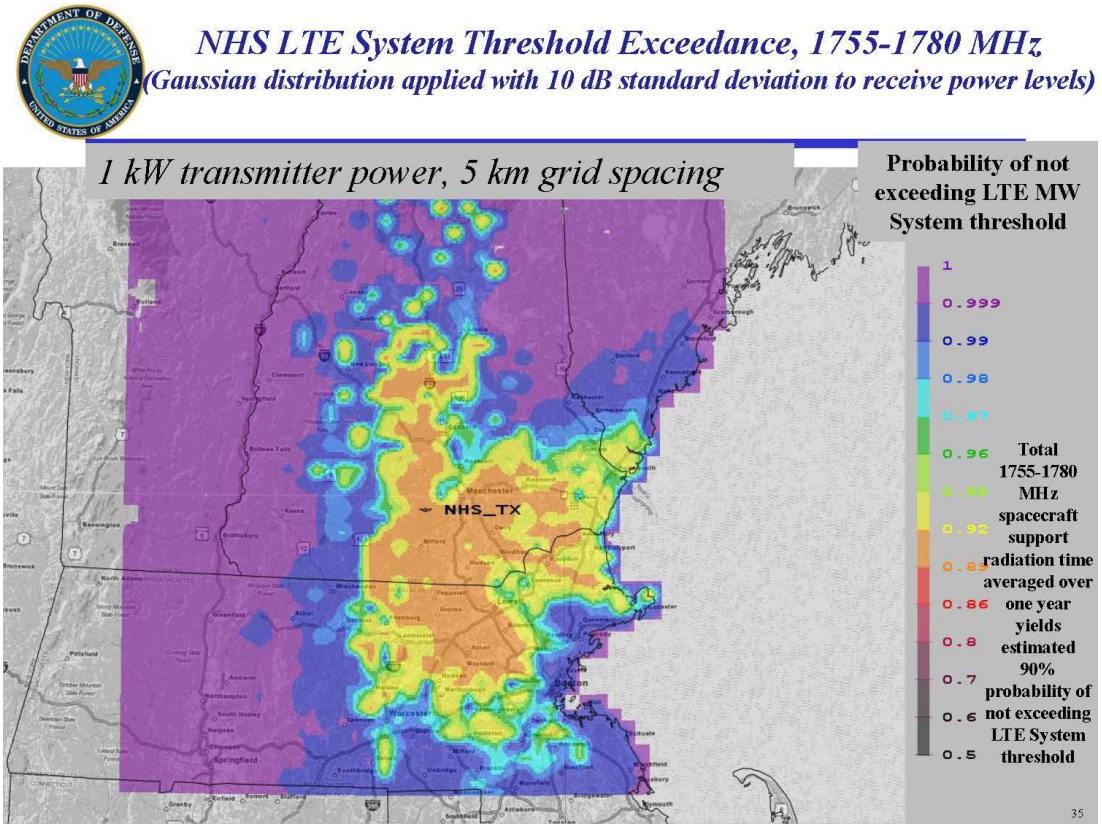
NHS Radiated Power
(18.6 dBW, max power example with attenuation)



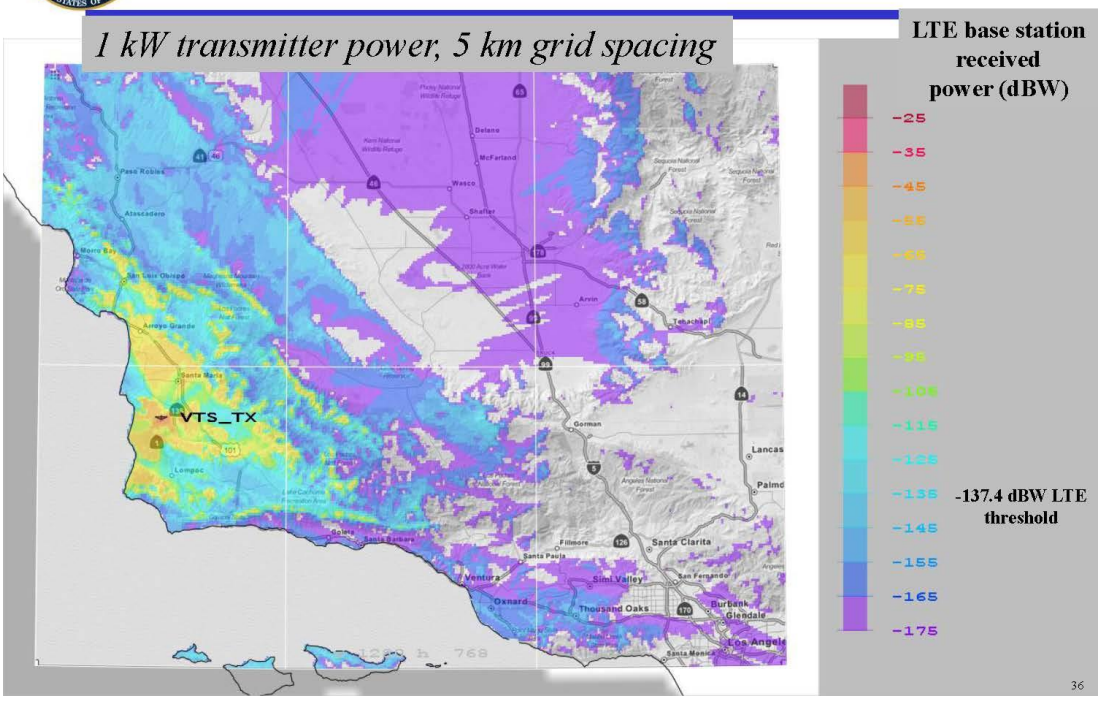
2241


NHS LTE System Threshold Exceedance, 1755-1780 MHz
(38.6 dBW, max power example)
7.244 kW transmitter power, 5 km grid spacing
Probability of not exceeding LTE MW System threshold
1
0.999
0.99
0.98
0.97
0.96
0.95
0.92
0.89
0.86
0.8
0.7
0.6
0.5
Total 1755-1780 MHz spacecraft support radiation time averaged over one year yields estimated 90% probability of not exceeding LTE System threshold
NHS_TX
34

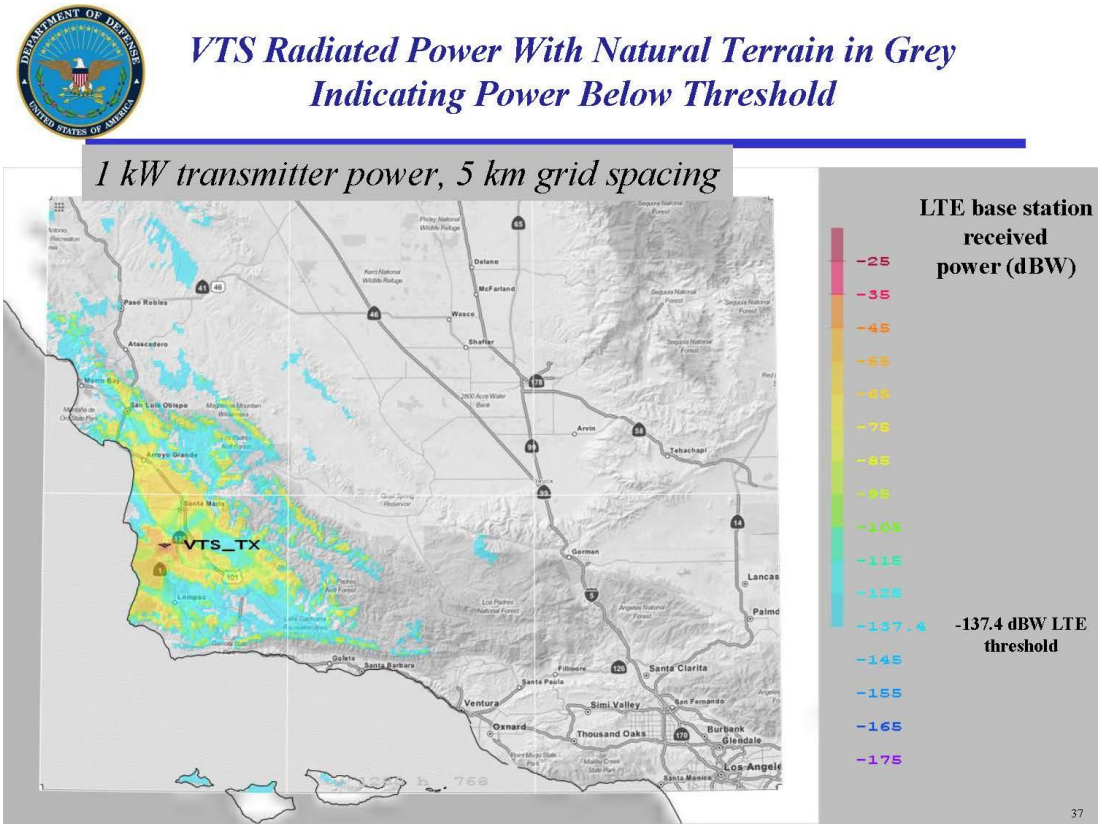
2242


NHS LTE System Threshold Exceedance, 1755-1780 MHz
(Gaussian distribution applied with 10 dB standard deviation to receive power levels)
1 kW transmitter power, 5 km grid spacing
Probability of not exceeding LTE MW System threshold
1
0.999
0.99
0.98
0.97
0.96
0.95
0.92
0.89
0.86
0.8
0.7
0.6
0.5
Total 1755-1780 MHz spacecraft support radiation time averaged over one year yields estimated 90% probability of not exceeding LTE System threshold
NHS_TX
35

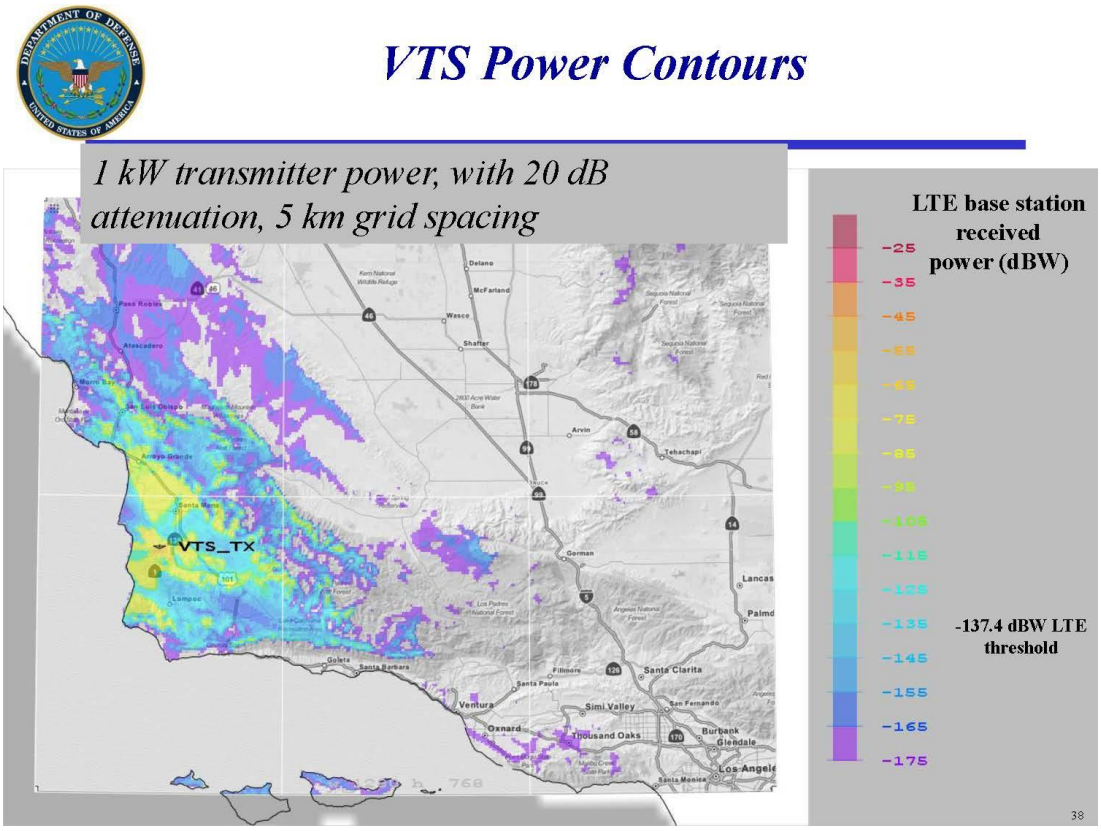
2243


VTS Power Contours
1 kW transmitter power, 5 km grid spacing
LTE base station received power (dBW)
-25
-35
-45
-55
-65
-75
-85
-95
-105
-115
-125
-135
-145
-155
-165
-175
-137.4 dBW LTE threshold
VTS_TX
Paso Robles
Atascadero
Morro Bay
San Luis Obispo
Arroyo Grande
Santa Maria
Lompoc
Delano
McFarland
Wasco
Shafter
Arvin
Tehachapi
Gorman
Lancas
Palmd
Goleta
Santa Barbara
Fillmore
Santa Paula
Ventura
Oxnard
Simi Valley
Thousand Oaks
Santa Clarita
San Fernando
Burbank
Glendale
Los Angele
Santa Monica
36

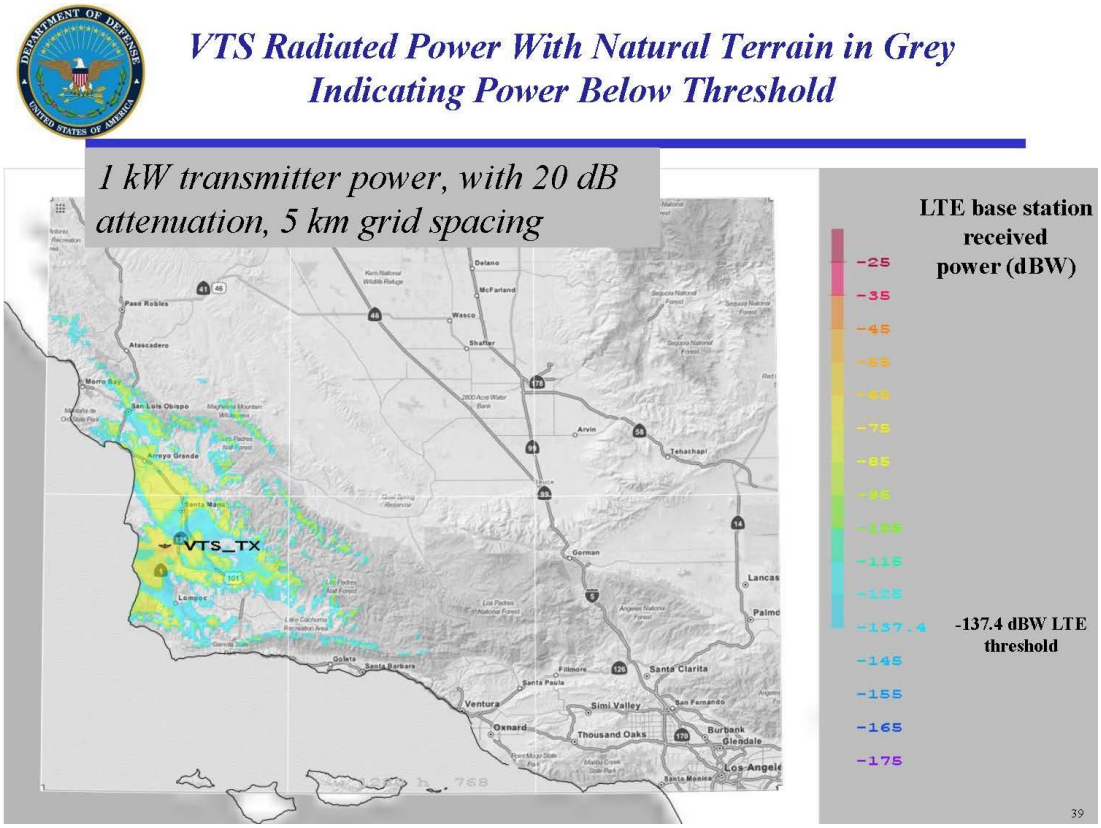
2244


VTS Radiated Power With Natural Terrain in Grey Indicating Power Below Threshold
1 kW transmitter power, 5 km grid spacing
LTE base station received power (dBW)
-25
-35
-45
-55
-65
-75
-85
-95
-105
-115
-125
-137.4
-145
-155
-165
-175
-137.4 dBW LTE threshold
VTS_TX
Paso Robles
Atascadero
Morro Bay
San Luis Obispo
Arroyo Grande
Santa Maria
Lompoc
Delano
McFarland
Wasco
Shafter
Arvin
Tehachapi
Gorman
Lancas
Palmd
Goleta
Santa Barbara
Fillmore
Santa Paula
Ventura
Oxnard
Simi Valley
Thousand Oaks
Santa Clarita
San Fernando
Burbank
Glendale
Los Angele
Santa Monica
37

2245

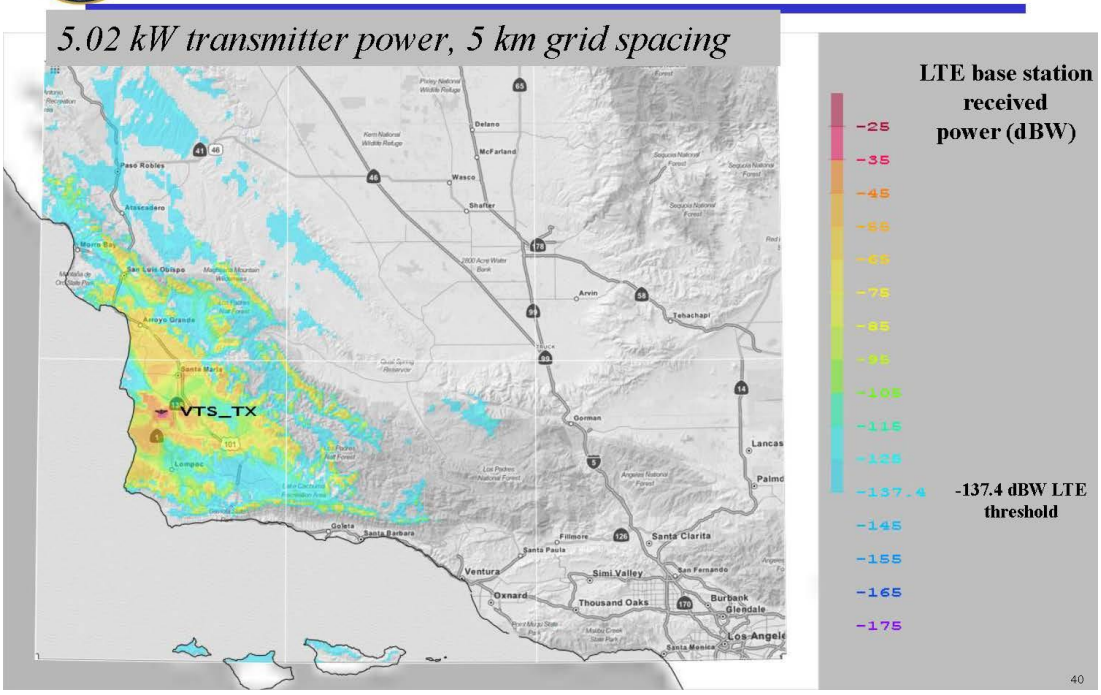

VTS Power Contours
1 kW transmitter power, with 20 dB attenuation, 5 km grid spacing
LTE base station received power (dBW)
-25
-35
-45
-55
-65
-75
-85
-95
-105
-115
-125
-135
-145
-155
-165
-175
-137.4 dBW LTE threshold
VTS_TX
Paso Robles
Atascadero
Morro Bay
San Luis Obispo
Arroyo Grande
Santa Maria
Lompoc
Goleta
Santa Barbara
Ventura
Oxnard
Santa Paula
Fillmore
Santa Clarita
Simi Valley
Thousand Oaks
San Fernando
Burbank
Glendale
Los Angeles
Santa Monica
Lancaster
Palmdale
Gorman
Tehachapi
Arvin
Shafter
Wasco
McFarland
Delano
38

2246


VTS Radiated Power With Natural Terrain in Grey Indicating Power Below Threshold
1 kW transmitter power, with 20 dB attenuation, 5 km grid spacing
LTE base station received power (dBW)
-25
-35
-45
-55
-65
-75
-85
-95
-105
-115
-125
-137.4
-145
-155
-165
-175
-137.4 dBW LTE threshold
VTS_TX
Paso Robles
Atascadero
Morro Bay
San Luis Obispo
Arroyo Grande
Santa Maria
Lompoc
Goleta
Santa Barbara
Ventura
Oxnard
Santa Paula
Fillmore
Santa Clarita
Simi Valley
Thousand Oaks
San Fernando
Burbank
Glendale
Los Angeles
Santa Monica
Lancaster
Palmdale
Gorman
Tehachapi
Arvin
Shafter
Wasco
McFarland
Delano
39

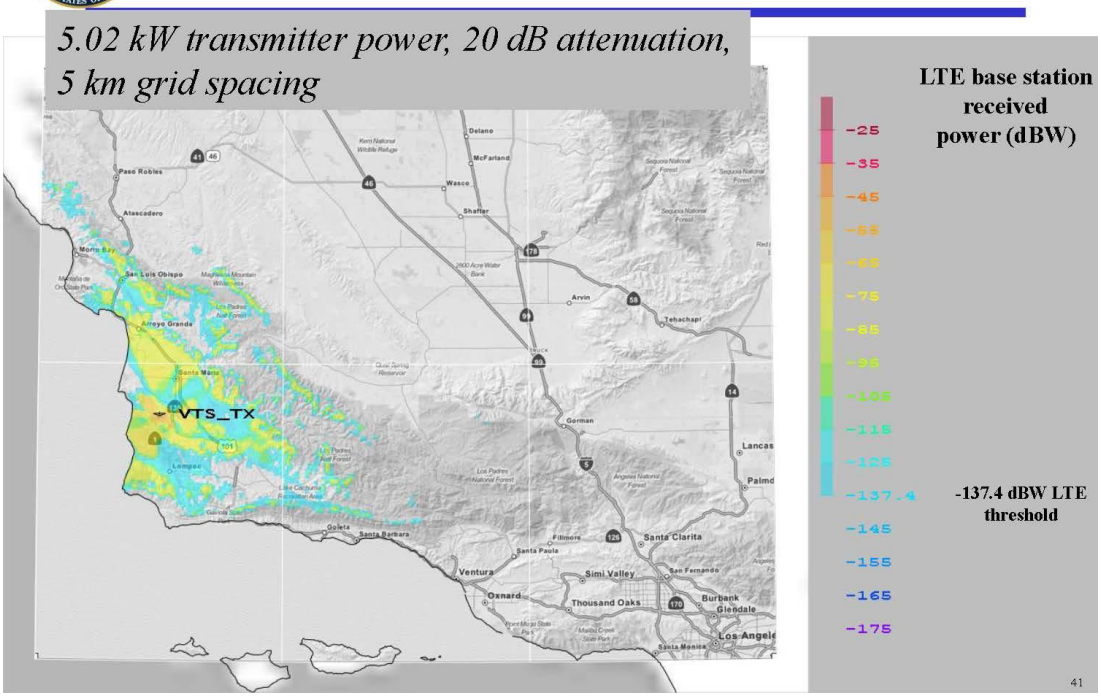
2247

VTS Radiated Power
(37.05 dBW, max power example)

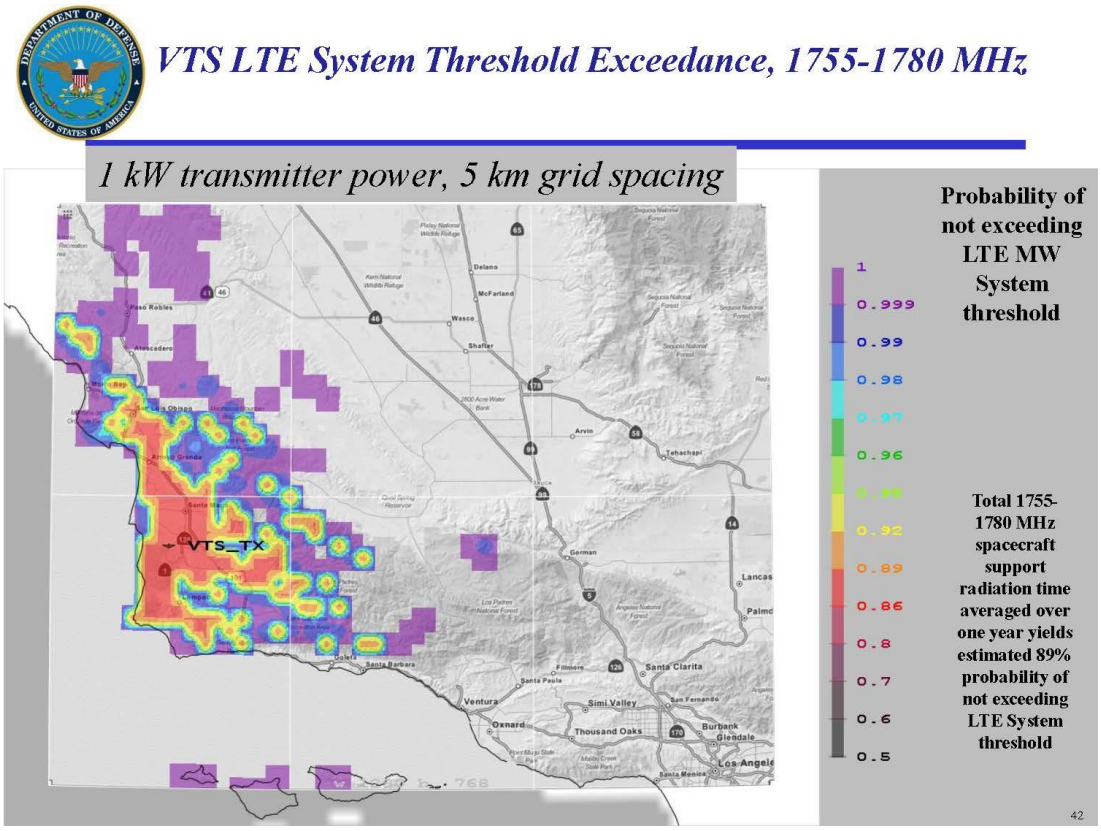


2248

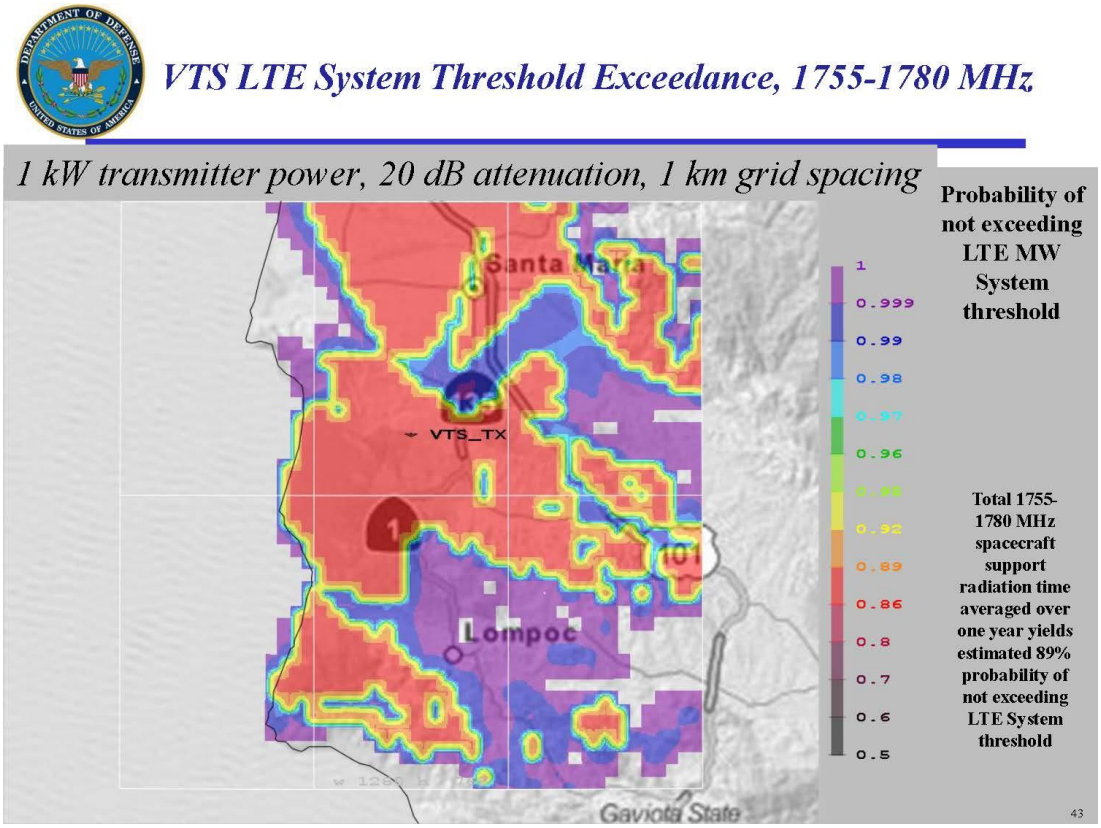
VTS Radiated Power
(17.05 dBW, max power with attenuation)



2249


VTS LTE System Threshold Exceedance, 1755-1780 MHz
1 kW transmitter power, 5 km grid spacing
VTS_TX
Probability of not exceeding LTE MW System threshold
1
0.999
0.99
0.98
0.97
0.96
0.95
0.92
0.89
0.86
0.8
0.7
0.6
0.5
Total 1755-1780 MHz spacecraft support radiation time averaged over one year yields estimated 89% probability of not exceeding LTE System threshold
42

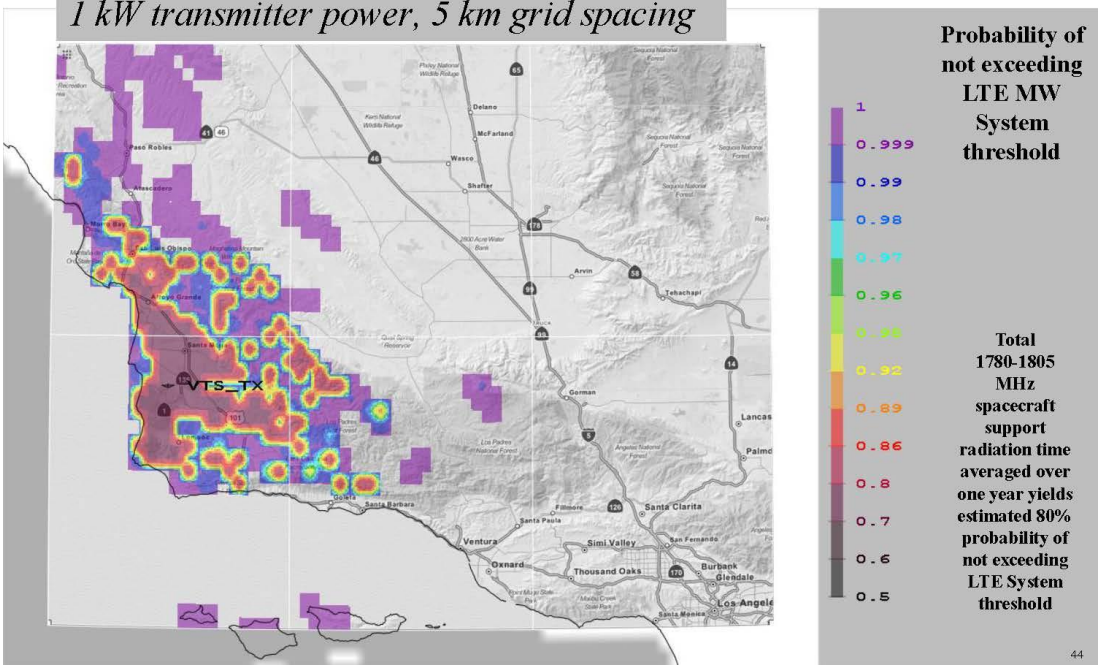
2250


VTS LTE System Threshold Exceedance, 1755-1780 MHz
1 kW transmitter power, 20 dB attenuation, 1 km grid spacing
Santa Maria
VTS_TX
Lompoc
Gaviota State
Probability of not exceeding LTE MW System threshold
1
0.999
0.99
0.98
0.97
0.96
0.95
0.92
0.89
0.86
0.8
0.7
0.6
0.5
Total 1755-1780 MHz spacecraft support radiation time averaged over one year yields estimated 89% probability of not exceeding LTE System threshold
43

2251

VTS LTE System Threshold Exceedance, 1780-1805 MHz

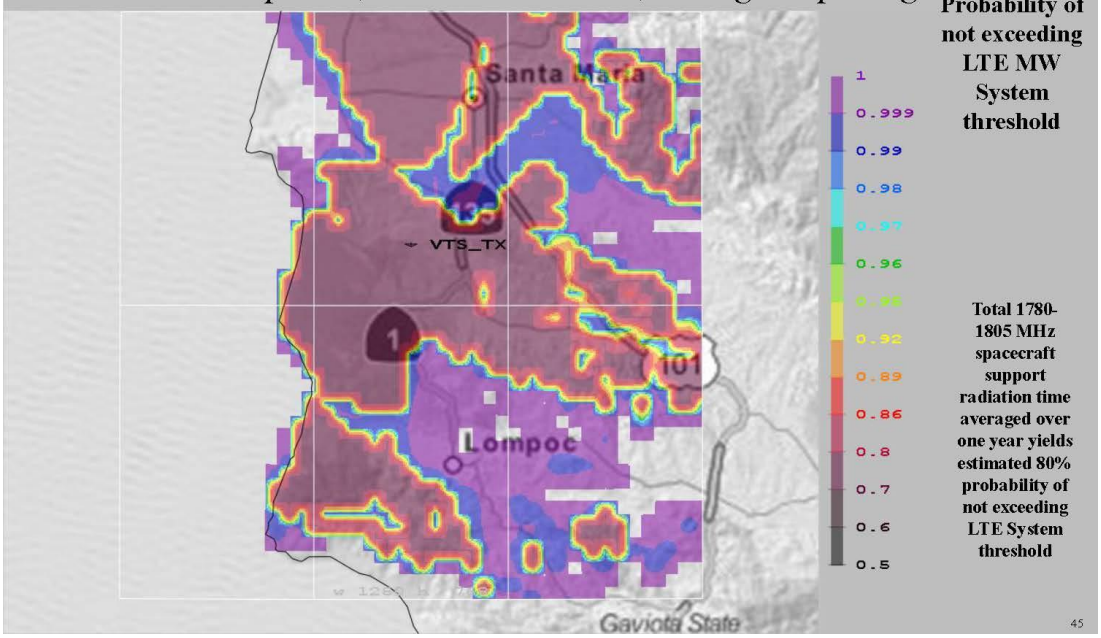
1 kW transmitter power, 5 km grid spacing



2252

VTS LTE System Threshold Exceedance, 1780-1805 MHz

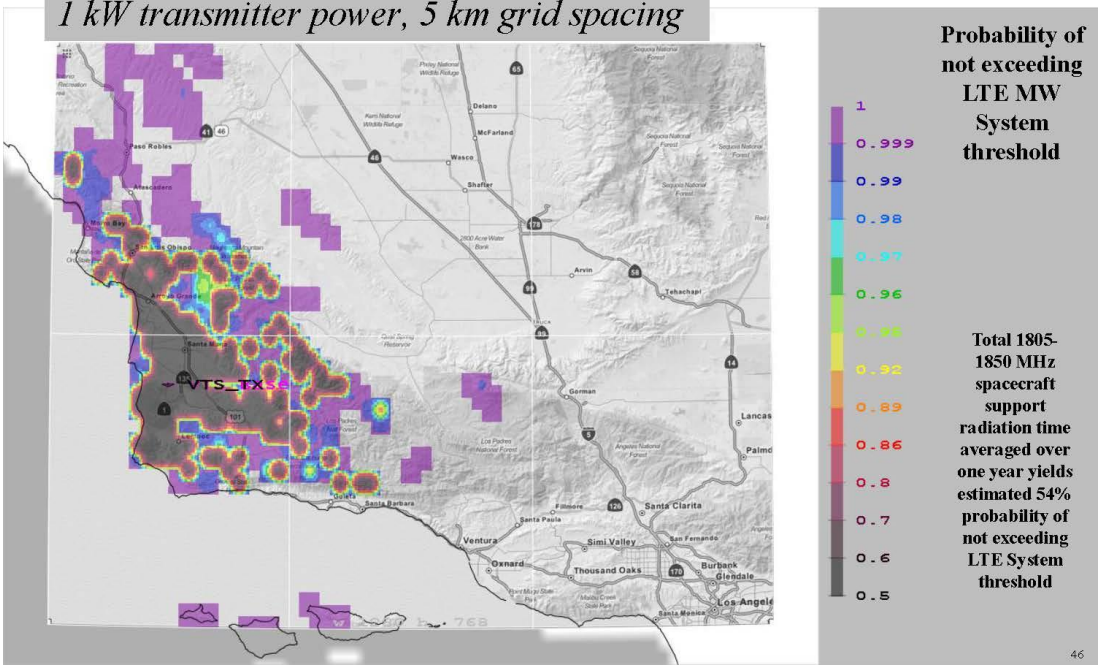
1 kW transmitter power, 20 dB attenuation, 1 km grid spacing



2253

VTS LTE System Threshold Exceedance, 1805-1850 MHz

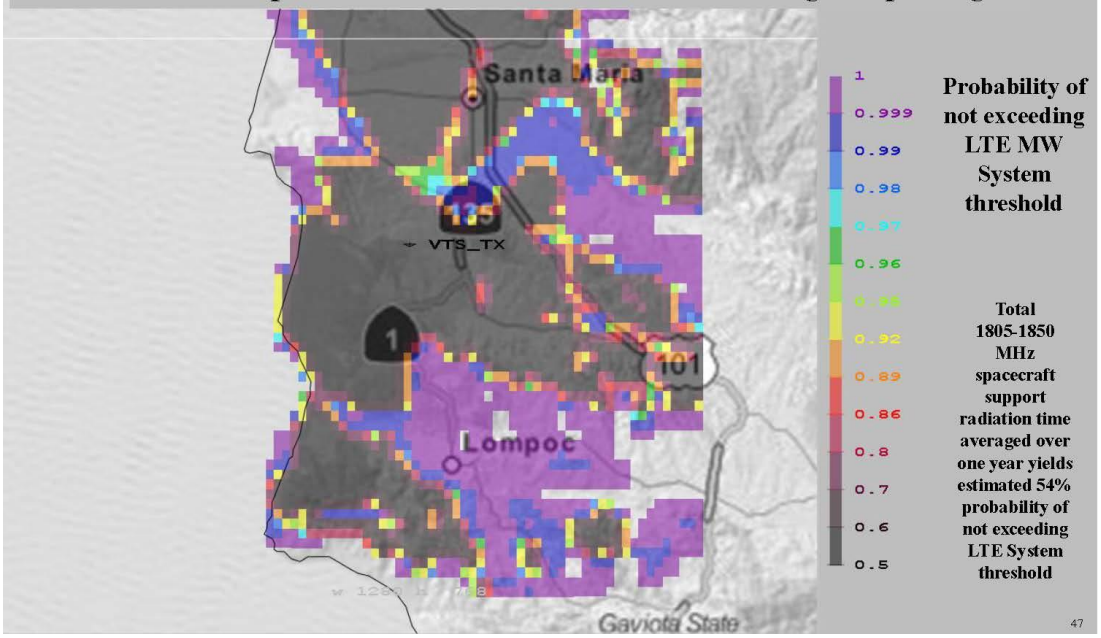
1 kW transmitter power, 5 km grid spacing



2254

VTS LTE System Threshold Exceedance, 1805-1850 MHz

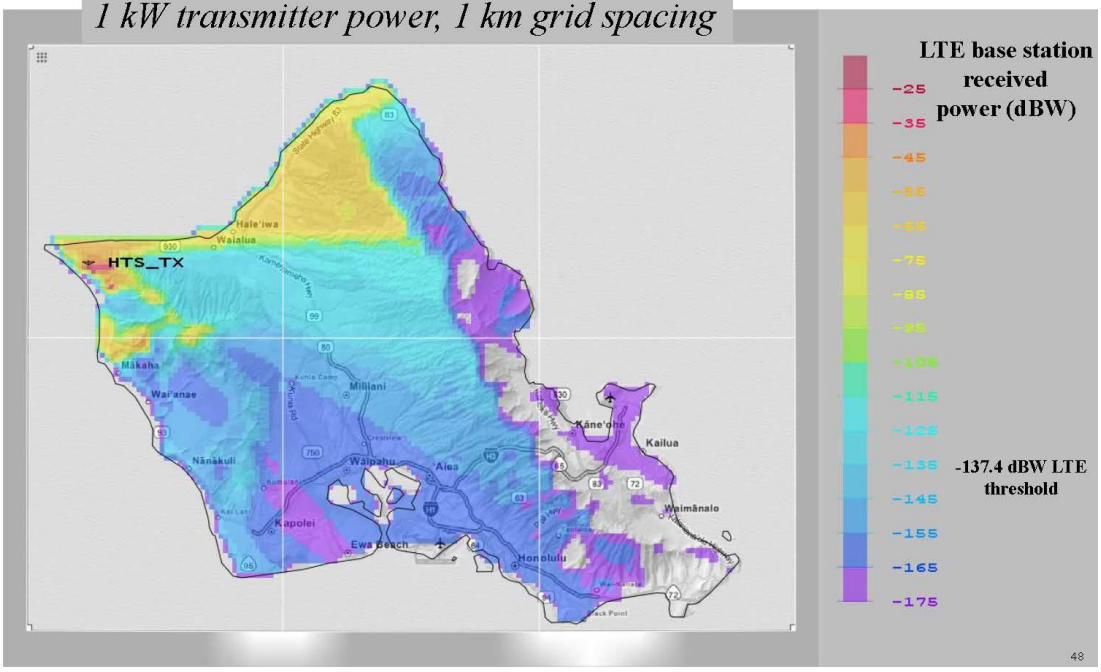
1 kW transmitter power with 20 dB attenuation, 1 km grid spacing



2255

HTS Power Contours

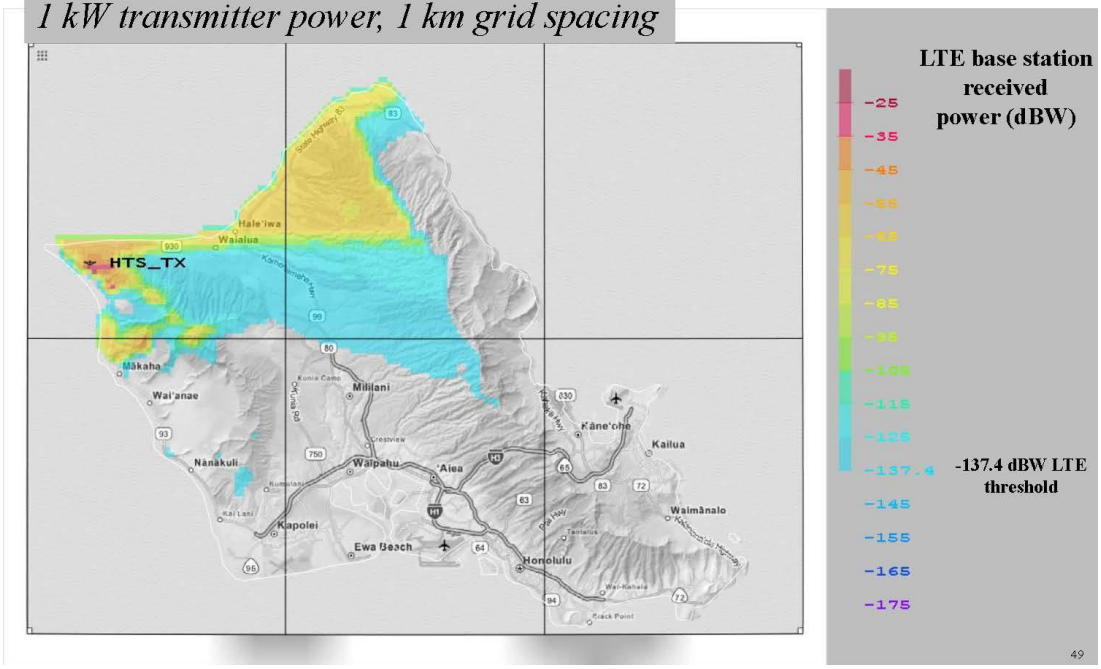
1 kW transmitter power, 1 km grid spacing



2256

HTS Radiated Power With Natural Terrain in Grey Indicating Power Below Threshold

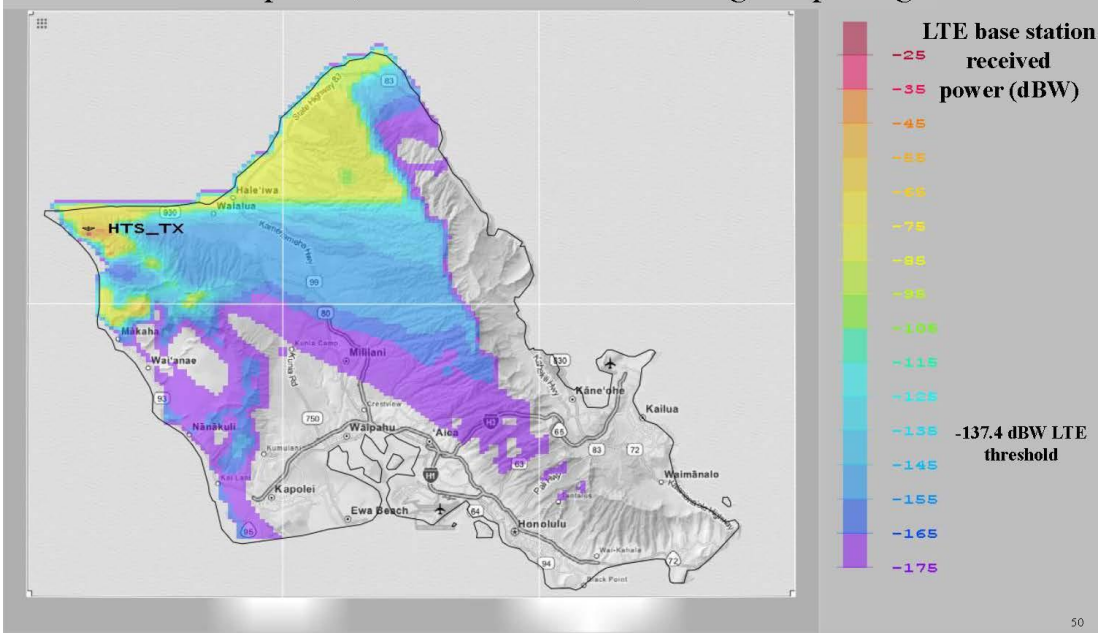
1 kW transmitter power, 1 km grid spacing



2257

HTS Power Contours

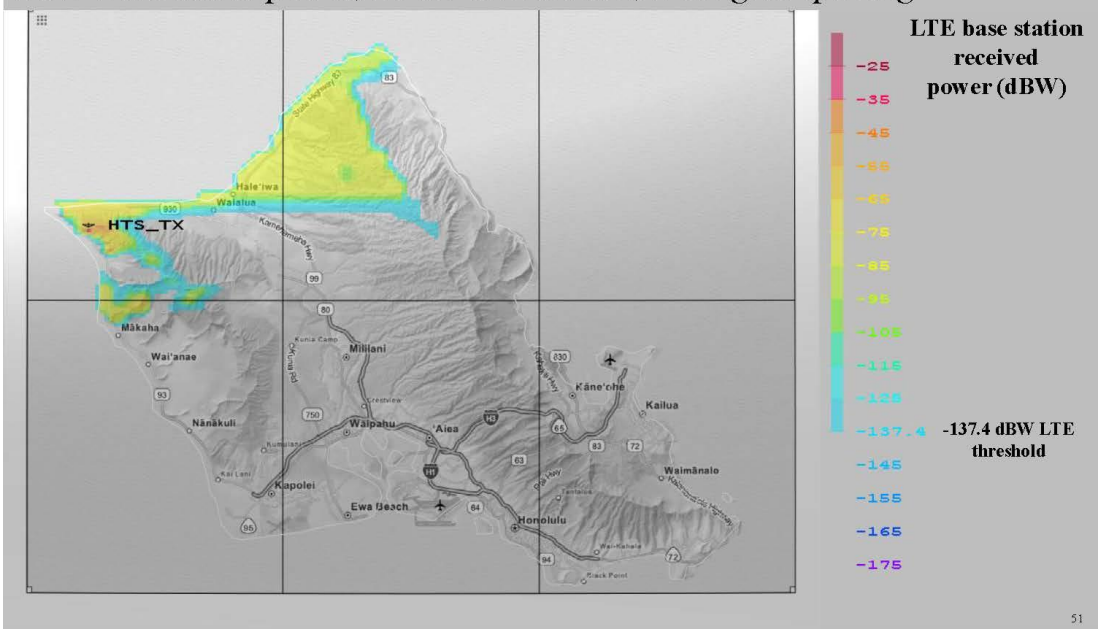
1 kW transmitter power, 20 dB attenuation, 1 km grid spacing



2258

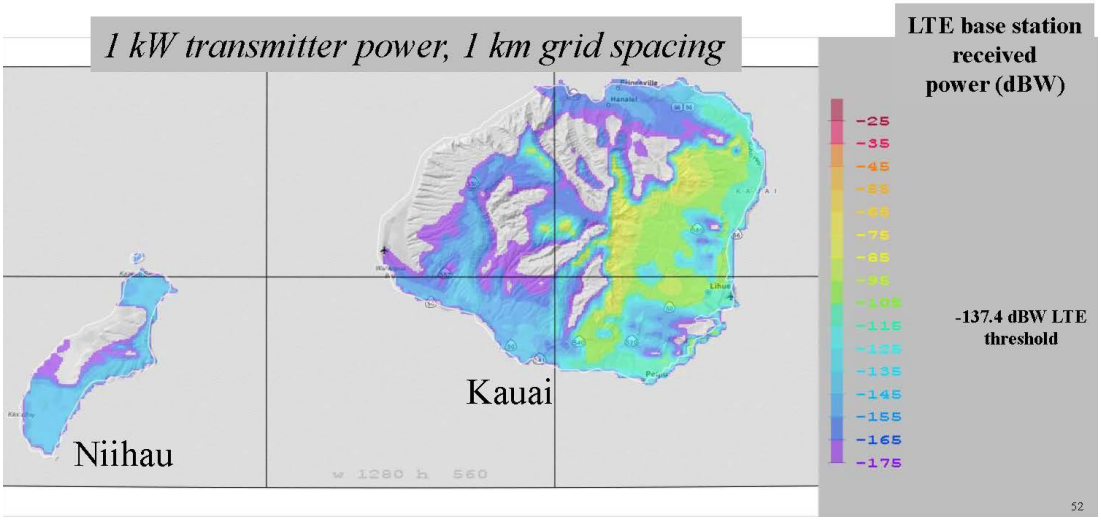
HTS Radiated Power With Natural Terrain in Grey Indicating Power Below Threshold

1 kW transmitter power, 20 dB attenuation, 1 km grid spacing



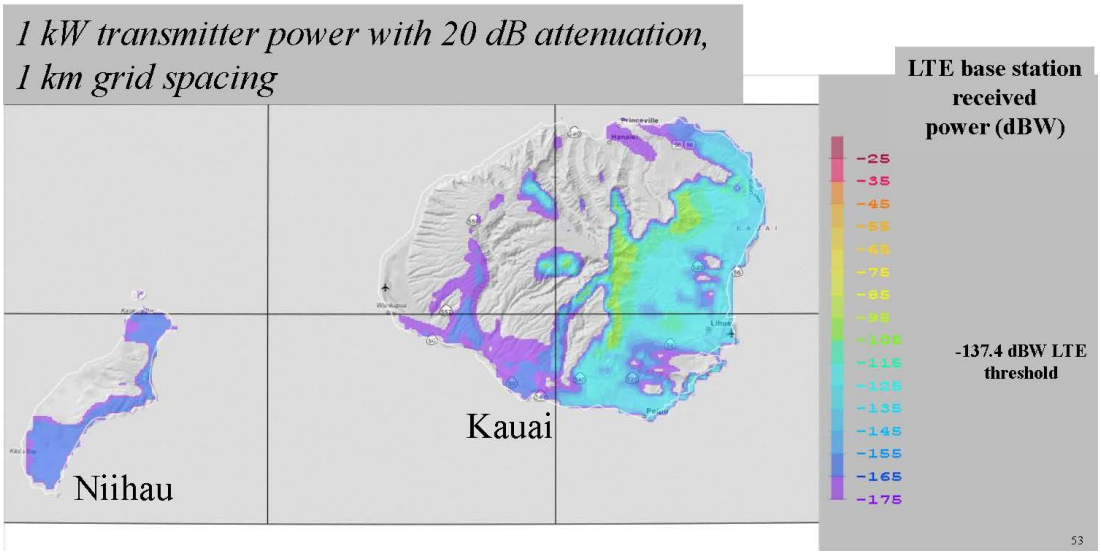
2259

HTS Power Contours



2260

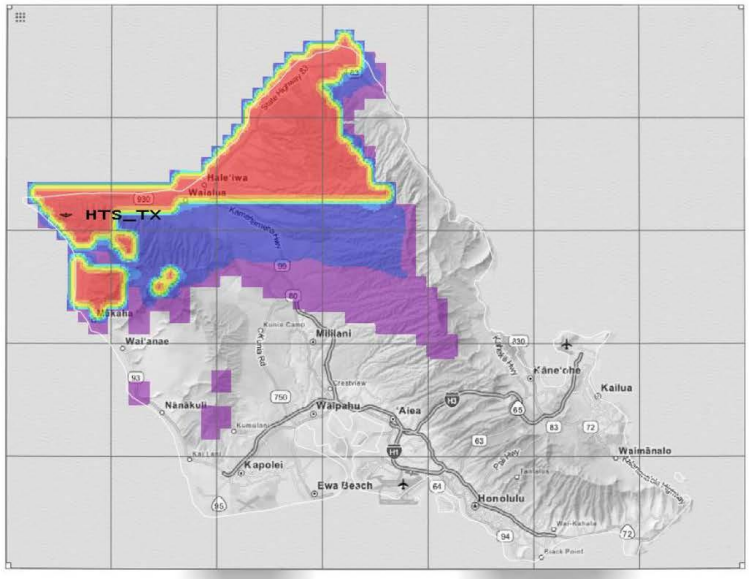
HTS Power Contours



2261

HTS LTE System Threshold Exceedance, 1755-1780 MHz

1 kW transmitter power, 1 km grid spacing



Probability of not exceeding LTE MW System threshold

1
0.999
0.99
0.98
0.97
0.96
0.95
0.92
0.89
0.86
0.8
0.7
0.6
0.5

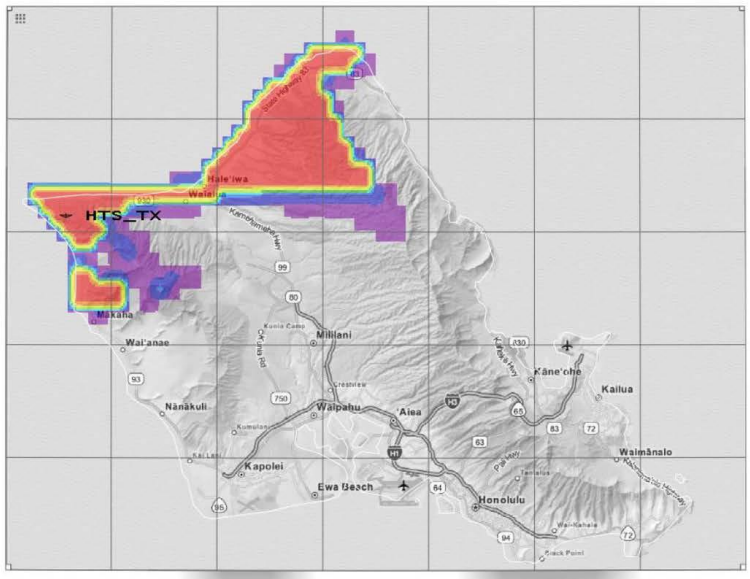
Total 1755-1780 MHz spacecraft support radiation time averaged over one year yields estimated 87% probability of not exceeding LTE System threshold

54

2262

HTS LTE System Threshold Exceedance, 1755-1780 MHz

1 kW transmitter power, 20 dB attenuation, 1 km grid spacing



Probability of not exceeding LTE MW System threshold

1
0.999
0.99
0.98
0.97
0.96
0.95
0.92
0.89
0.86
0.8
0.7
0.6
0.5

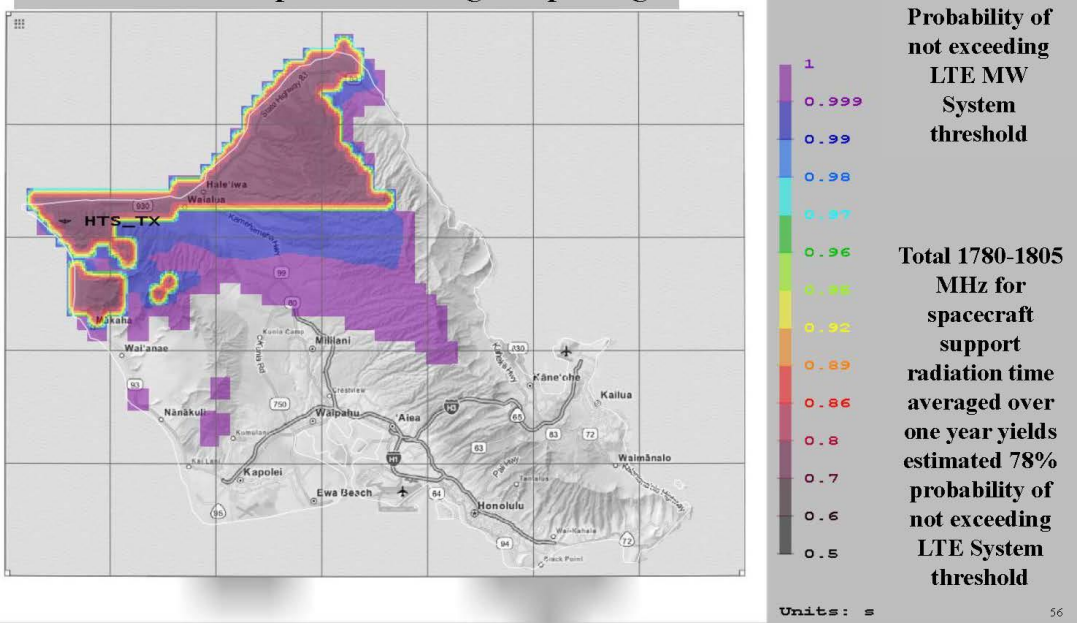
Total 1755-1780 MHz spacecraft support radiation time averaged over one year yields estimated 87% probability of not exceeding LTE System threshold

55

2263

HTS LTE System Threshold Exceedance, 1780-1805 MHz

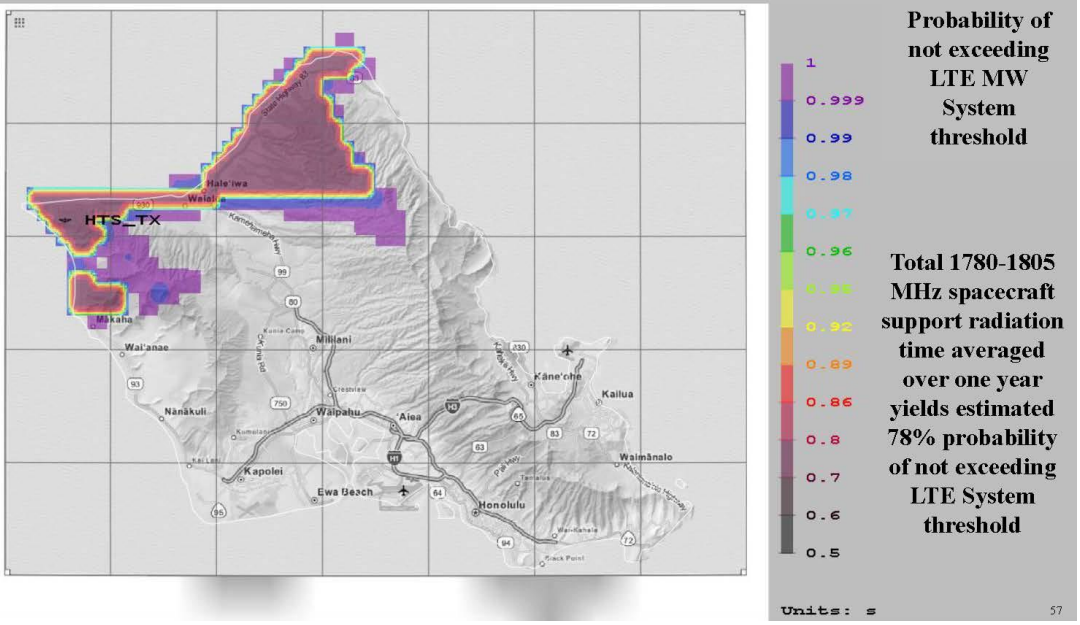
1 kW transmitter power, 1 km grid spacing



2264

HTS LTE System Threshold Exceedance, 1780-1805 MHz

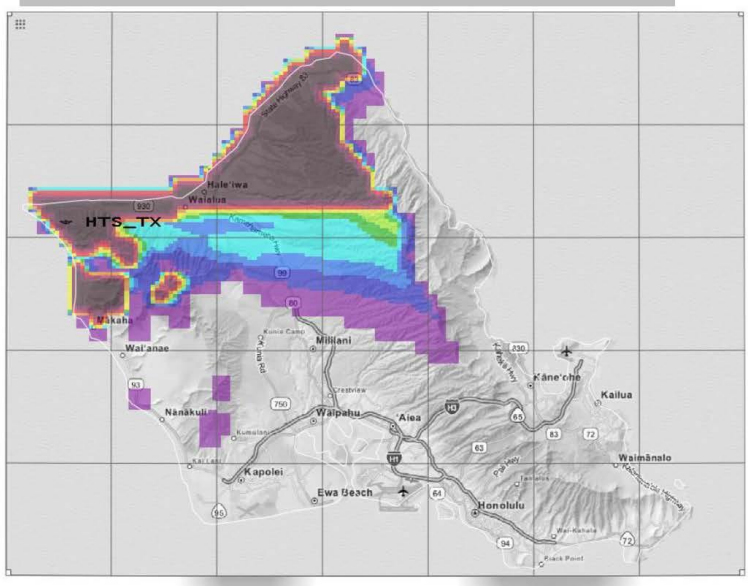
1 kW transmitter power, 20 dB attenuation, 1 km grid spacing



2265

HTS LTE System Threshold Exceedance, 1805-1850 MHz

1 kW transmitter power,1 km grid spacing



Probability of not exceeding LTE MW System threshold

1
0.999
0.99
0.98
0.97
0.96
0.95
0.92
0.89
0.86
0.8
0.7
0.6
0.5

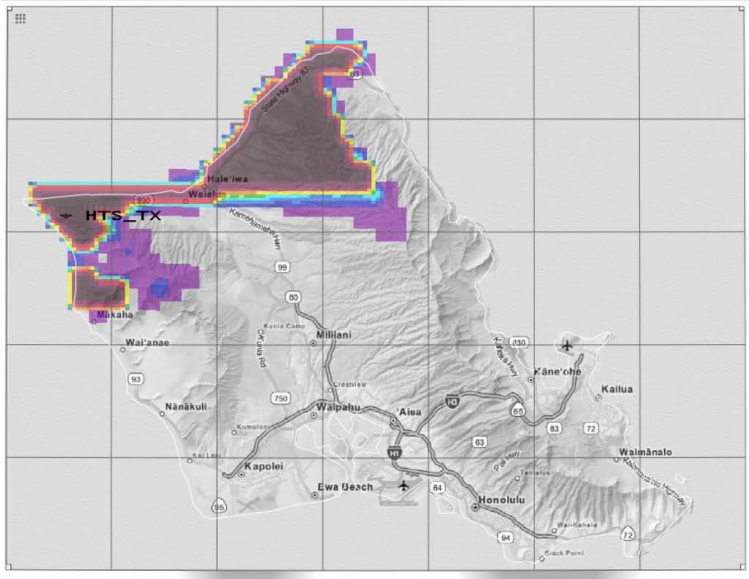
Total 1805-1850 MHz spacecraft support radiation time averaged over one year yields estimated 69% probability of not exceeding LTE System threshold

58

2266

HTS LTE System Threshold Exceedance, 1805-1850 MHz

1 kW transmitter power, 20 dB attenuation, 1 km grid spacing



Probability of not exceeding LTE MW System threshold

1
0.999
0.99
0.98
0.97
0.96
0.95
0.92
0.89
0.86
0.8
0.7
0.6
0.5

Total 1805-1850 MHz spacecraft support radiation time averaged over one year yields estimated 69% probability of not exceeding LTE System threshold

59

2267