The Case for an Enduring Spatial Science

John P. Wilson
17th AGILE Conference on Geographic Information Science
4 June 2014

Outline

- Spatial roots
  - Geography
  - Landscape architecture
  - Computer science
- The (current) opportunity
- Guiding principles
  - Spatial as an enabling discipline
  - Core concepts (& distractions)
  - Role of collaboration
  - Changing character of spatial data in a fast changing world
  - Role of geodesign | actionable science
- Final Thoughts

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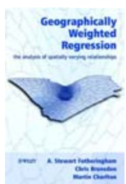
Spatial roots | geography

- Representation
- Classification
- Analysis
- Visualization



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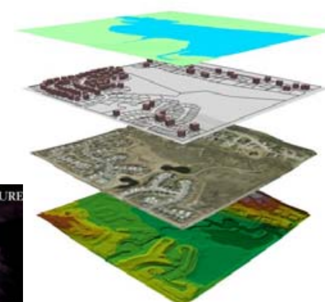
Spatial roots | landscape architecture



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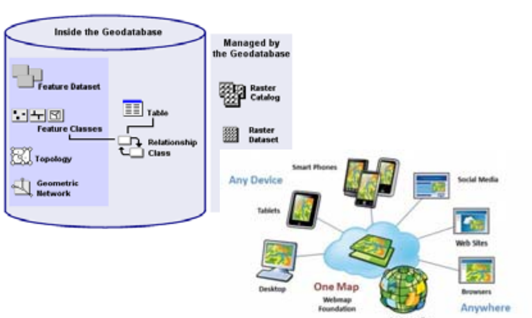
Spatial roots | computer science



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The opportunity

- Spatial turn
  - Rapid spread of spatial thinking & GIS throughout sciences
    - Snow's 19th century work on cholera
    - Scholten's new book
    - ACM GIS conference series
  - Swept through social sciences and humanities as well
    - All human action literally *takes place* somewhere
    - Spatial dimension of social interaction key for understanding all of the classic questions about the human condition
- New academic units
- New academic programs

Map showing clusters of cholera cases in London epidemic of 1854

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Five guiding principles

- Spatial as an enabling discipline
- Core concepts | distractions
- Role of collaboration
- Changing character of spatial data
- Geodesign | actionable science

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Spatial as an enabling discipline

- Cf. with statistics
- Need small number of fundamental spatial scientists, larger numbers of translational scientists?
- Know ourselves, our role in the knowledge discovery process
  - o GIS&T Body of Knowledge projects
- Learn how to connect & collaborate with others

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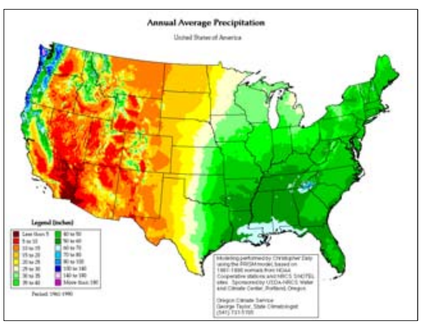
Core concepts | Duckham 2014

Spatial structure

Dynamism
Uncertainty
Cognition
Design
Scale



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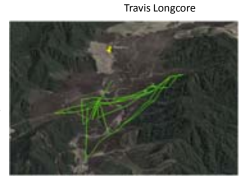
Dynamism

Catalina Island Fox, Photo: Courtesy of Tim Coonan

Mission Blue Butterfly, Photo: Courtesy of Travis Longcore



Poronui Lodge: Home Ranges for Stags

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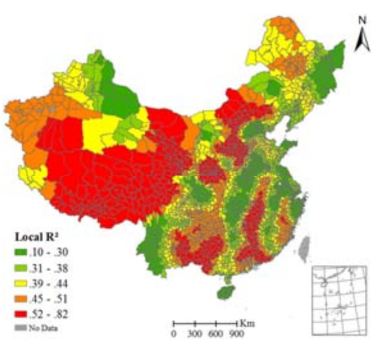
Uncertainty



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Cognition

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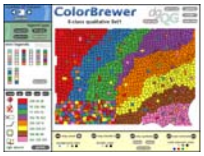
Design



Maps

Technology

1:25K 1:50K 1:100K

Scale | complexity

Global	Cloud cover and CO2 levels control primary energy inputs to climate and weather patterns
Meso	Prevailing weather systems control long-term mean conditions; elevation-driven lapse rates control monthly climate; and geological substrate exerts control on soil chemistry
Topo	Surface morphology controls catchment hydrology; slope, aspect, horizon, and topographic shading control surface insolation
Micro	Vegetation canopy controls light, heat, and water for under-story plants; vegetation structure and plant physiognomy controls nutrient use
Nano	Soil microorganisms control nutrient recycling

(Slide: Courtesy of Michael Hutchinson)

Distractions

esri HEXAGON USGS MDA FOSS4G EUROPE BREMEN2014 Bentley DIGITALGLOBE GE Energy GeoEye Hitz Hitachi Zosen Ubisense CyberGIS

GeoComputation 2007

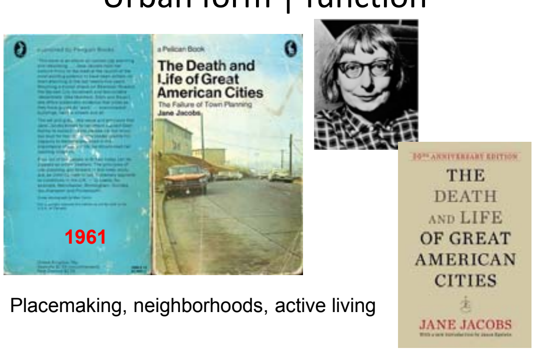
The Art and Science of Solving Complex Spatial Problems with Computers.

OGC Making location count. www.opengeospatial.org

Role of collaboration

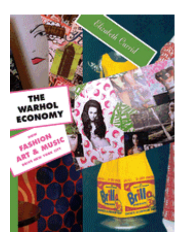
- Work with scientists in other domains
- Tackle "big" questions in new and important ways
  - Use of taxi, cell phone & social media data to explore form and function of metropolitan regions, cities, etc.
- **Key criteria for success …**
  - **Collaboration needs to involve more than spatial scientists**
  - **Sum of the parts must be greater than the parts themselves**

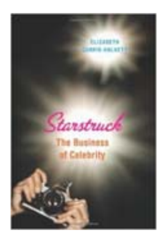
Urban form | function



Placemaking, neighborhoods, active living

Economic organization

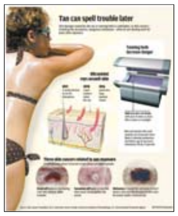




Industry in Motion: Using Smart Phones to Explore the Spatial Network of the Garment Industry in New York City
Sarah Williams
Elizabeth Currid-Halkett
PLOS ONE
2014

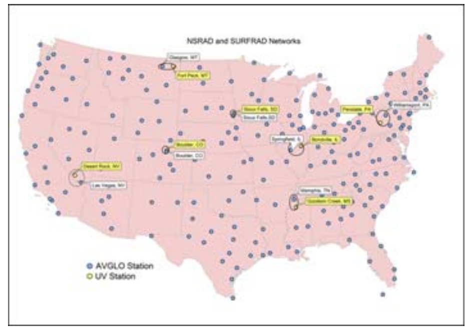
Melanoma risk …

- One of most rapidly increasing cancers among white population in U.S.
- Studies consistently point to UV exposure as most important risk factor
- Individual sun exposure has proved difficult to quantify
- Initial research question …
  - **How well can we model spatial variations in UV radiation given measurement network & interpolation techniques available?**

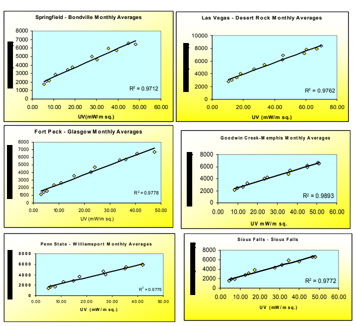


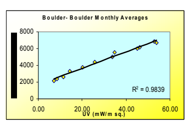
Collaborative work with Myles Cockburn (USC Keck School of Medicine) & Zaria Talatovich (National Cancer Institute)

Measurement network



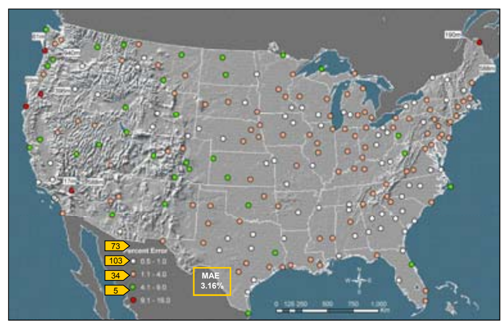
Radiation data correlations



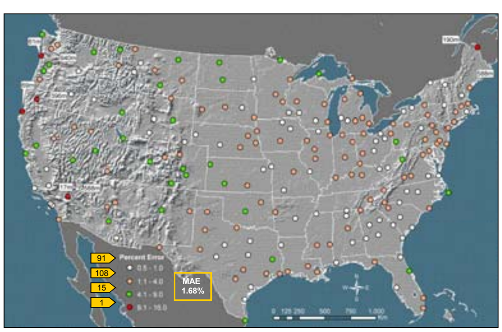


Springfield – Bondville, IL
Las Vegas – Desert Rock, NV
Boulder – Boulder, CO
Fort Peck – Glasgow, MT
Goldwin Creek – Memphis, TN
Penn State – Williamsport, PA
Sioux Falls – Sioux Falls, SD

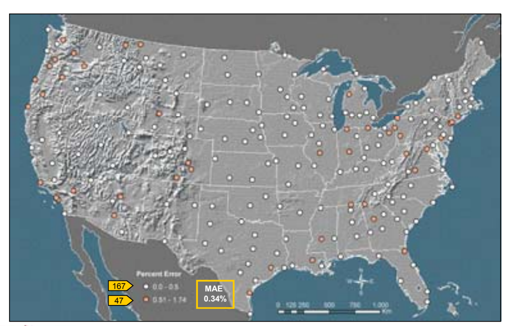
Thiessen error map



Kriging error map

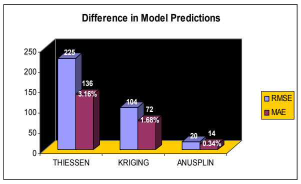


Spline Error Map



Model differences

- Spline predictions 11 & 2.2 times better than Thiessen polygon & kriging predictions
- ANUSPLIN …
  - Smallest RMSE, MAE & VE
  - Highest R (observed / predicted)
  - Smallest R (observed / error)



	RMSE	MAE	VE	Correlation OBS/PRED	Correlation OBS/ERR
THIESSEN	225	136 (3.16%)	50906	0.90	0.40
KRIGING	104	72 (1.68%)	10885	0.98	0.31
ANUSPLIN	**20**	**14 (0.34%)**	**384**	**0.99**	**0.15**

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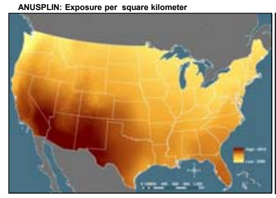
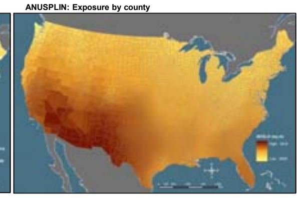
ANUSPLIN UV exposure model

- **Used Arc/Info GRID tools to calculate zonal means**
- **Generated map of UV exposures by county**

ANUSPLIN: Exposure per square kilometer



ANUSPLIN: Exposure by county



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Case control dataset

- Los Angeles County Cancer Surveillance Program
  - 820 melanoma cases among white, non-Hispanic residents < 65 yrs
  - Cases older than 65 yrs excluded to minimize recall bias of events occurring in young age
  - Controls included 877 individuals who lived nearby and that were matched to cases for ethnicity, age, and gender
- Structured interviews
  - Residential history from birth to time of interview recorded as county or country of residence (if outside USA)
  - Time spent at each residence reported in years
  - Time spent in outdoor activity (average number of days per year of outdoor activity during age periods 15-24, 24-44, >44 yrs of age)

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Statistical analysis

- Second research question …
  - **How is incidence of melanoma connected to place of residence and time spent outdoors?**
- Conditional logistic regression used to estimate odds ratios for melanoma
  - Cumulative lifetime exposure: 4 classes (<150,000, 150-200,000, 200-250,000, >250,000 Wh/m^2)
  - Analysis of time spent in outdoor activity in 3 age-specific classes because exposure at young age is important?
  - Self-reported time spent in outdoor activity: 4 classes (0-50, 51-100, 101-200, >200 days per year)
  - Examined 45+ year age group because younger adults have less chance for exposure and we controlled for matching variables of age, sex and socio-economic status

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Cumulative UV exposure

Cumulative exposure (Wh/m^2)	Case-control	OR
< 150,000	118/143	1
150,000-200,000	160/174	1.62
200,000-250,000	168/201	2.64
> 250,000	215/191	6.01
p-Value		< 0.0001

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UV adjusted time spent outdoors

45+ years	Case-control	OR	*p*-Value
UV adjusted outdoors, 15-24 years			
< 558,800	90/121	1	
558,800-1,042,671	123/124	1.33	
> 1,042,671	122/122	1.55	0.0955 (0.0333)
UV adjusted outdoors, 25-44 years			
< 294,330	110/120	1	
294,330-645,333	125/125	1.91	
> 645,333	105/121	0.99	0.74 (0.61)
UV adjusted outdoors, 44+ years			
< 299,720	123/121	1	
299,720-609,600	99/120	0.86	
> 609,600	116/127	0.91	0.74

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Changing character of spatial data

- Finer granularity in terms of both space and time …
  - o Digital terrain modeling
  - o Exposure modeling
- 3D
- Crowdsourcing | Volunteered Geographic Information
- Social media
- Sensing systems
- Changing role of government

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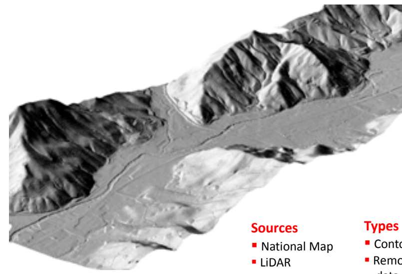
Digital terrain modeling



Sources
- National Map
- LiDAR
- IFSAR
- GPS

Types
- Contour and stream line data
- Remotely sensed elevation data
- Surface specific point elevation data

Picture: Courtesy of David Maune

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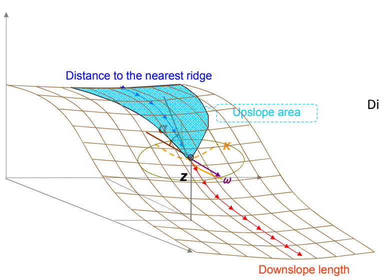
Topographic attributes



Elevation (*z*)
Slope gradient (*α*)
Slope aspect (ω)
Curvatures (κ)
Distance to the nearest ridge
Downslope length
Upslope area

Slide: Courtesy of Bard Romstad

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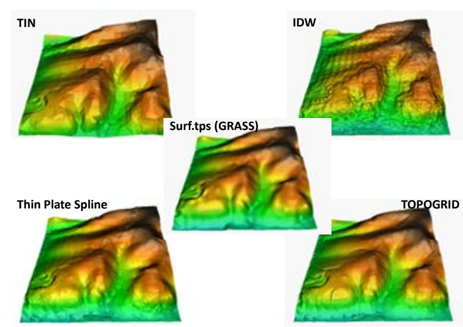
Sparse data | spatial interpolation



Slide: Courtesy of Graeme Aggett

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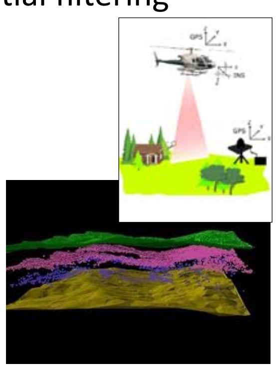
LiDAR | spatial filtering

- **Li**ght **D**etection **A**nd **R**anging
- Measures distance to, or other properties of a target by illuminating target with light, using pulses from a laser
- Three components
  - Airborne scanning laser rangefinder
  - Differential GPS
  - Internal Navigation System
- Generates millions of points at relatively low cost …



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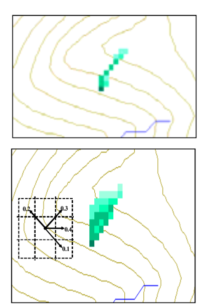
Pre-processing decisions

- **Need to focus on fundamental science as well as tools**
- Source and granularity of DEM used
- Presence and handling of spurious pits (interpolation)
- Choice of drainage enforcement option (if any)
- Choice of flow routing algorithm
- Dynamic character of key variables and processes
- **Depiction of topographic shape matters most!**



Maps: Courtesy of David Tarboton

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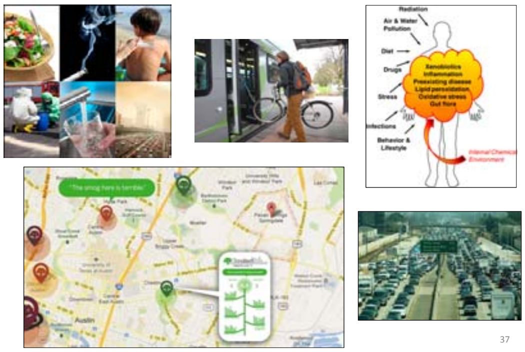
The exposome



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3D | LiDAR surface models

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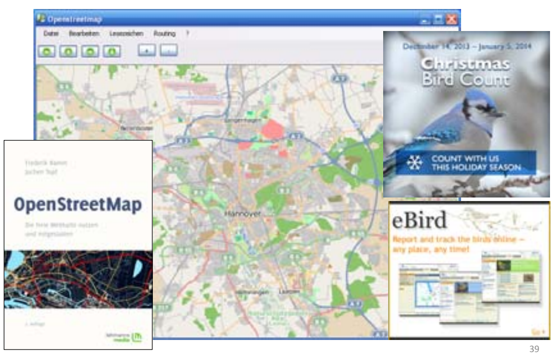
Crowdsourcing | VGI



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Crowdsourcing | social media

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GeoSensor networks

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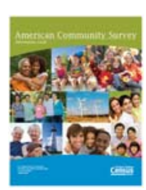
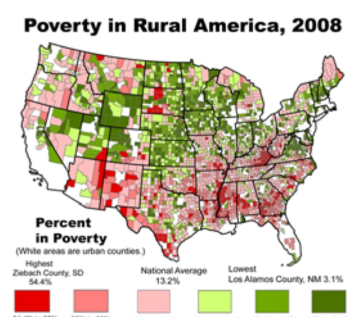
Changing role of government

American Community Survey





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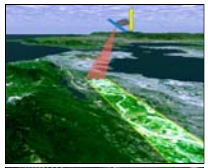
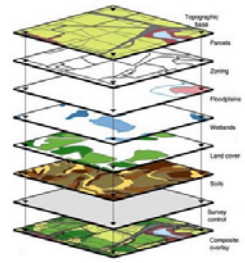
Geodesign

- Focuses on spatial thinking
  - New field built on spatial sciences base
- Leverages geospatial technologies
  - Sketching
  - Computation
- Focuses on the future
- Focuses on design as a force for good and precursor to action
- Focuses on collaboration
  - Multi-disciplinary
  - Stakeholders and general public
  - Special role for Web



Small- and big-D design

- Small D design
  - Simple optimization problem
- Large D design
  - Varying goals among stakeholders
  - Feedback loops that modify objectives
  - Inclusion of new constraints and data as the process proceeds
  - Uncertainties about implementation
  - Messy!

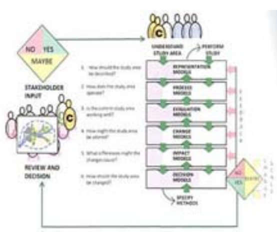


McHarg's Constraining Design Approach

Source: Goodchild (2010)

Six stages of geodesign

- Simple | Complex Models
- Key Participants
  - The people of the place
  - Experts (i.e. technically competent people)
  - All will need to take more active roles
- Drivers of change
  - Political attitudes
  - Information technologies



Source: Steinitz (2012)

Reality Check LA (2002)

http://www.youtube.com/watch?v=-aHglh6m3ns

Role of the Web

UCSB | Marine Science Lab

- SeaSketch
  - Specify geographic area of interest
  - Upload map services from ArcGIS Online
  - Create and invite users and groups to participate in projects
  - Define sketch classes for marine management zones
  - Create map-based discussion forums
  - Create simple surveys to collect data on human uses of ocean
- MarineMap
- Spatial marine planning

Final thoughts

- Spatial as an enabling discipline
- Core concepts | distractions
- Role of collaboration
- Changing character of spatial data
- Geodesign | "actionable" science

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Our past work …

- Focused on terrestrial environments
- Focused on space (less about time)
- Focused on what is or what has been
- Ignored most of the world …
  - o Oceans – cover 70% of Earth's surface
  - o Buildings – people spend 85% of their lives indoors & dense urban areas have far more interior space than land area
- Not well aligned with everyday places & non-expert users
- Not connected to sketch & recording needs of design disciplines

USC spatial sciences

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Spatial education

- Geographic information
  - **Tells us "what is where when"**
- Spatial science …
  - A visual science (maps)
  - An "enabling" science like statistics
- Supported by rapidly expanding suite of geographic information technologies
- **High entry cost has been & still is a barrier to widespread adoption and use**
- Esri's new $1 billion ArcGIS Online gift to U.S. schools

Spatial @ USC …

- New undergraduate programs
  - o GE courses (incl. "Numbers & Maps")
  - o Spatial Studies Minor
  - o **GeoDesign B.S. degree**
- New progressive degree programs
- New graduate programs
  - o GIS&T M.S. degree
  - o GIS&T Graduate Certificate
  - o Geospatial Intelligence Graduate Certificate
  - o Geospatial Leadership Graduate Certificate
  - o **GeoHealth track in Master of Public Health degree**

Multiple entry points
Multiple pathways
Multiple exit points

USC spatial sciences

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Geodesign | placemaking

Spatial thinking
Geospatial technologies
Focus on the future
Design as a force for good
Collaboration

Capacity building
Human well-being
Sustainable development

Spatial leadership
Professional ethics

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Close | Questions?

Project for Public Spaces

Placemaking plans

City-wide strategic plans

Capacity building and cultural change

Placemaking 101
Lighter
Quicker
Cheaper

http://www.pps.org/

John Wilson
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