A Geodesign Research Agenda / Map

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Geodesign Summit

Jan 2015

Introduction and Rationale

What to tackle:

- what's known, what's unknown, what's answerable (& unanswerable?) ...

Why?

- to encourage fruitful collaborations, shared language, identify voids, guide future work & engage education
- evidence of success of geodesign methods will promote rapid uptake, evidence of problems will help us fix them

Lessons and Questions from Practice

Original questions: @GSD circa 1998:
Why don’t designers use GIS? -> What could GIS learn from designers?

Today: (Flaxman / GeodesignTech) research-oriented practice

3 case studies, each with different concerns and starting points

Example Regional Studies

- Florida Beaches HCP – Endangered Species Act
- NSF Ecohydrology – Ecosystem Services Science
- BLM Great Basin – Modernizing ‘resource assessment' methods to include design/policy alternatives

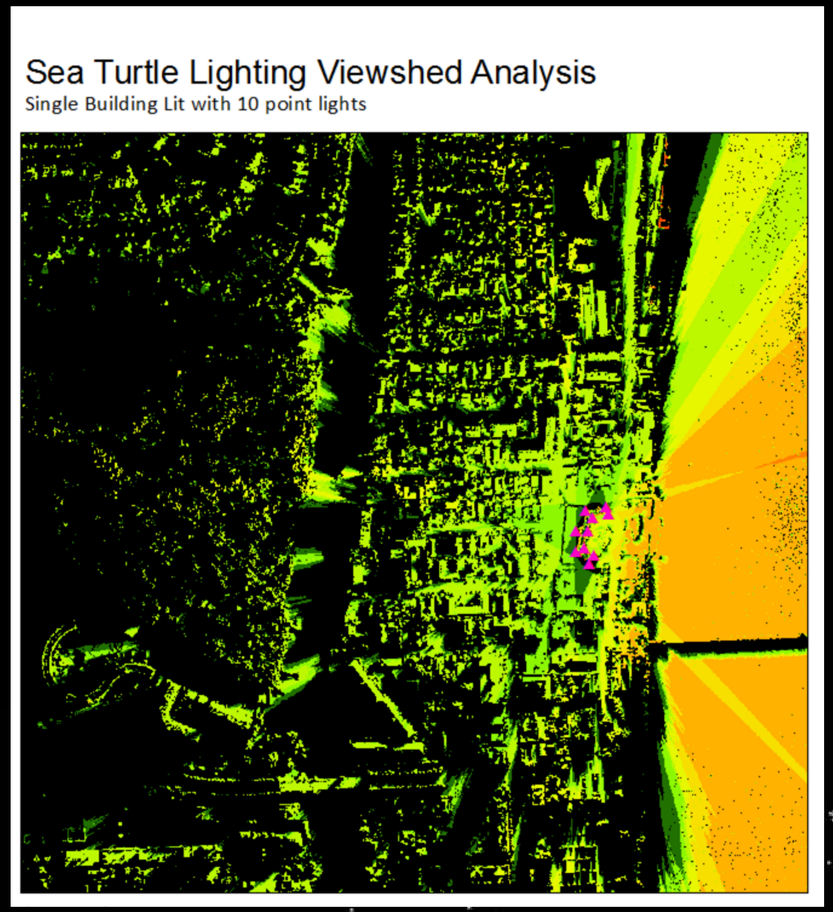
GEODESIGN TECHNOLOGIES

Florida Beaches HCP
Starting Context

- Traditional impact assessment framework
- But with minimization and mitigation accounting (ESA Section 10 not 8)
- Huge scope
  400 miles of beach
  16 species
  50 permit types
  10k permits/year
  6 Years of meetings…

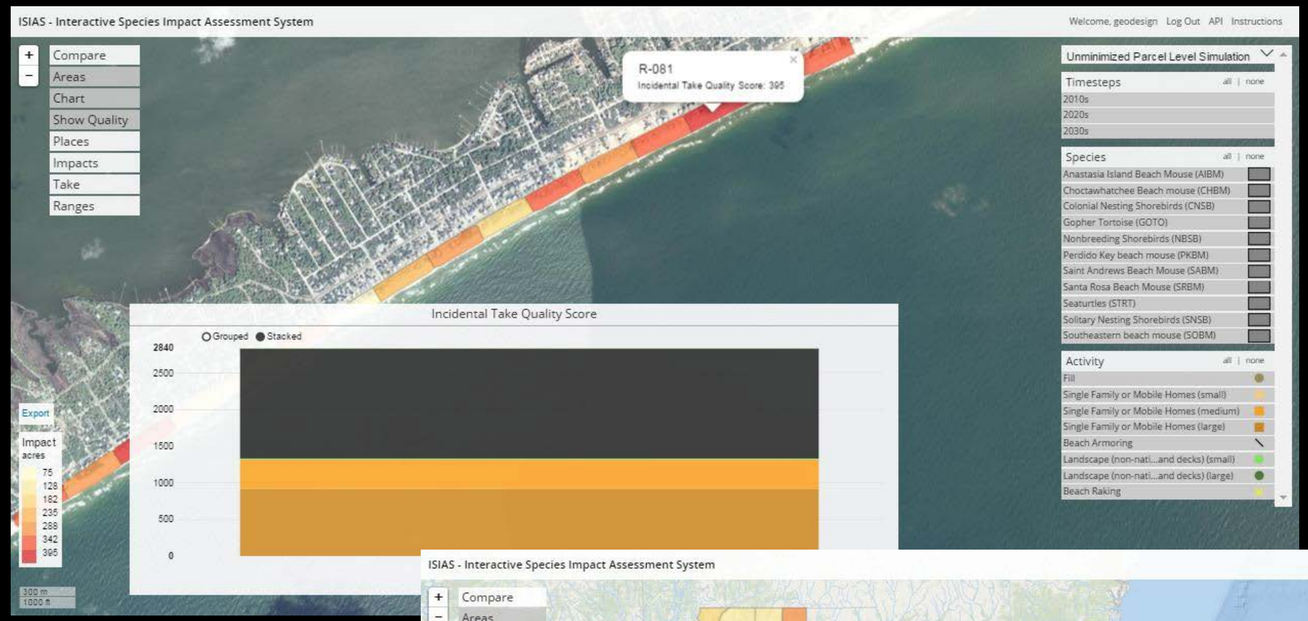
Project 1:
Florida Beaches HCP

- Project underway for 2 years before I was hired. Why?
  - Had ignored impact of sea level rise on beaches
  - Didn’t have a technical framework capable of simulating biological impacts at scale
  - Didn’t have conceptual framework to target minimization and mitigation, or account for it quantitatively

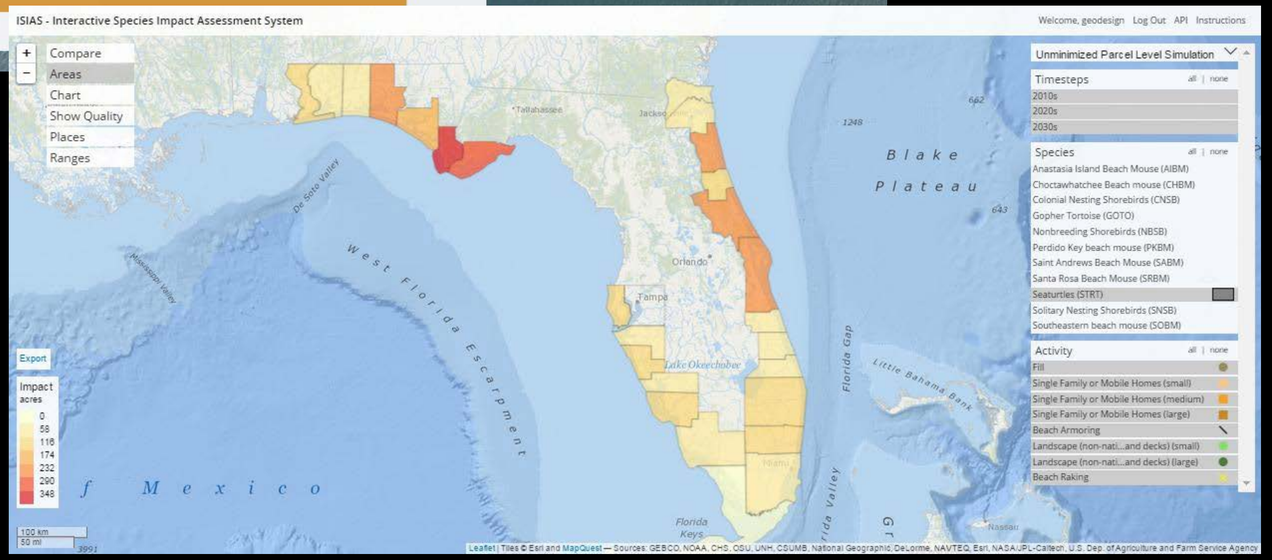


Florida Beaches HCP
What's Been Done

- Created contextual scenarios which look specifically at SLR & beach development
- Created an interactive online impact assessment system supporting ~100 participants
- Developing mitigation plan scenarios



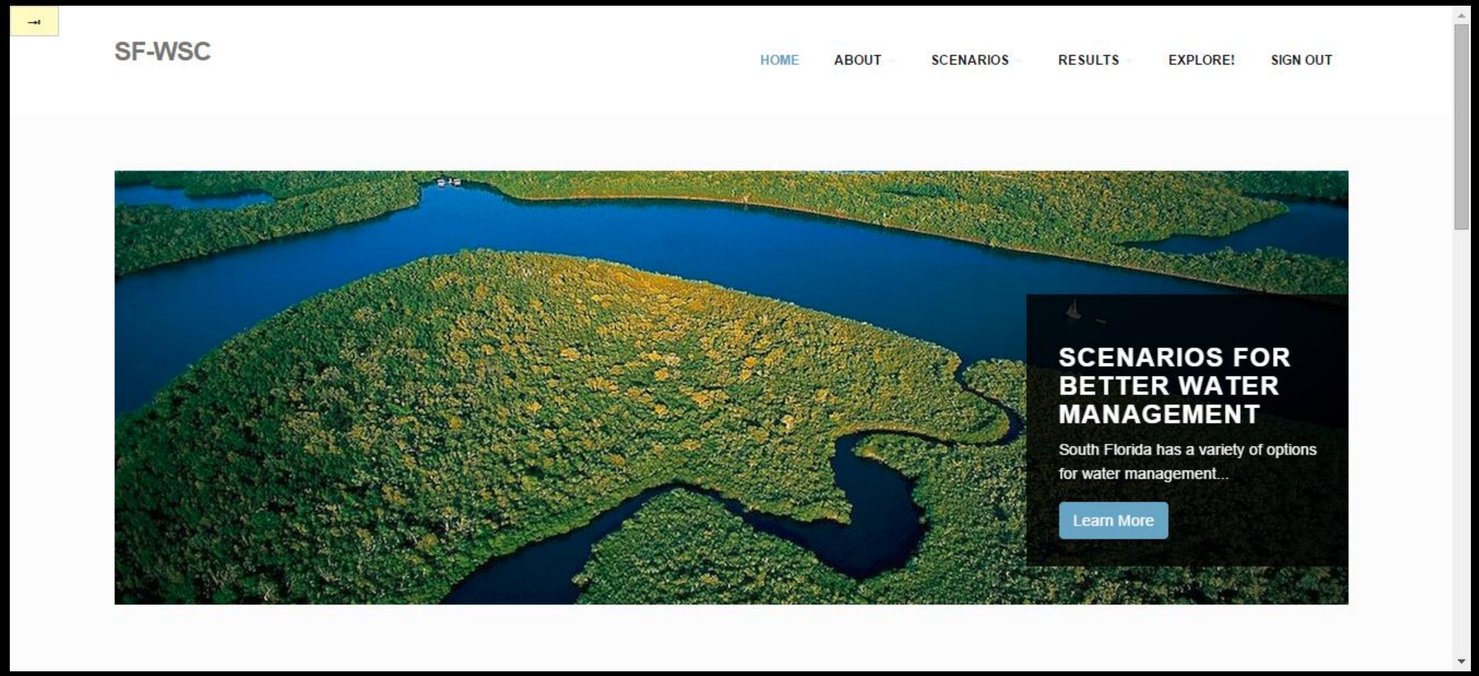
Interactive Impact Assessment



Interactive Mitigation Planning

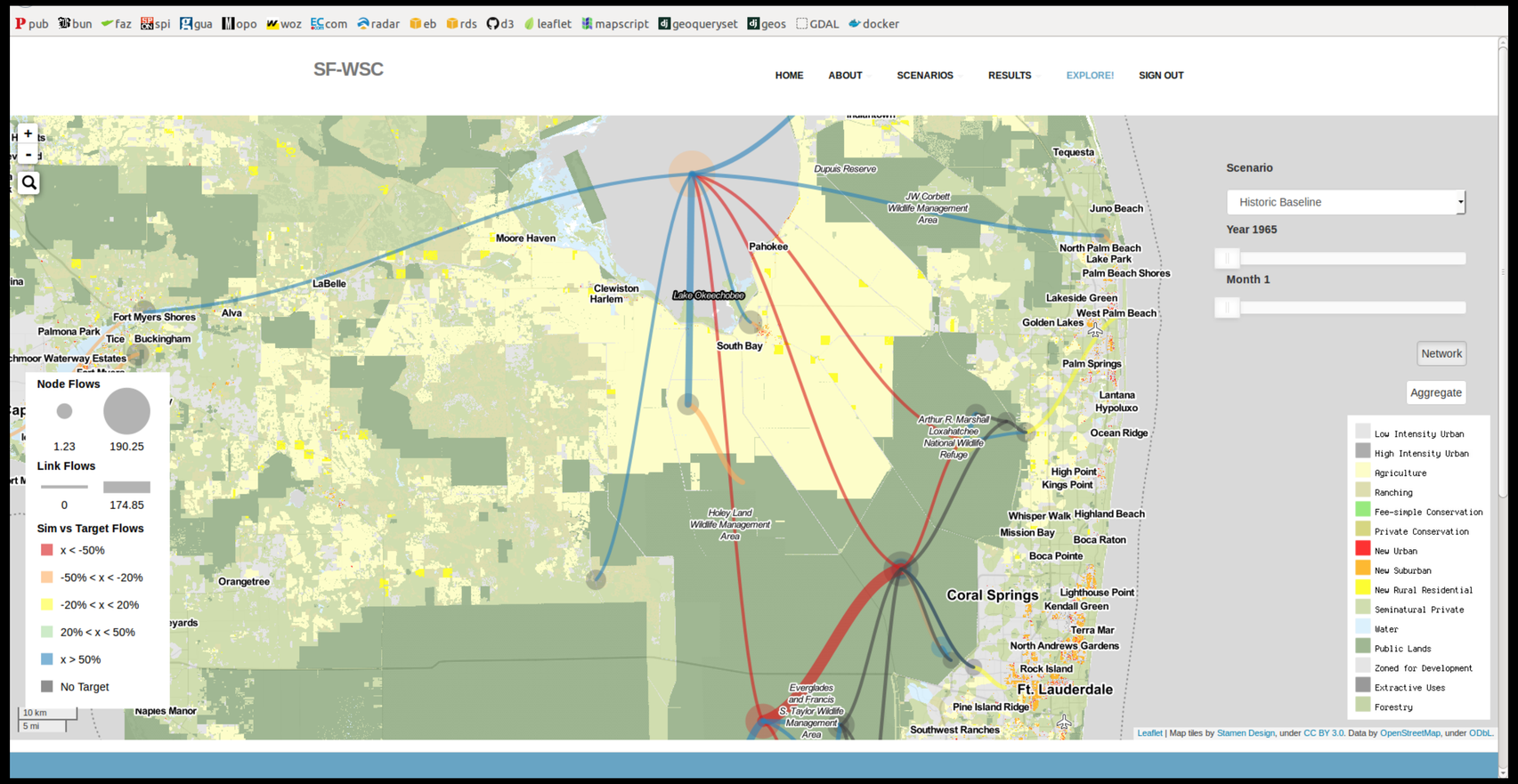
NSF Hydroecology Study Context

- Large science research study.
- Responsible for “scenario planning” within an ecosystem services quantification project
- Goal: generate scenarios and tools for managing water & green infrastructure better



NSF Hydroecology Study
Work Done to Date

- Created online scenario platform integrating diverse land use, climate & hydro data
- Developing geovisualizations to explain what “getting the water right” might look like



Great Basin Alternative Futures: Context

- BLM-sponsored effort, in advance of large new federal & state commitments for Sage-Grouse restoration (millions of acres of land use change).

- Prior “REA” planning effort done standard way, considering single future

Great Basin Alternative Futures: Goals & Methods

- Leverage prior planning & impact assessment work
- Extend to consider human choice (covering millions of acres), climate change & working lands

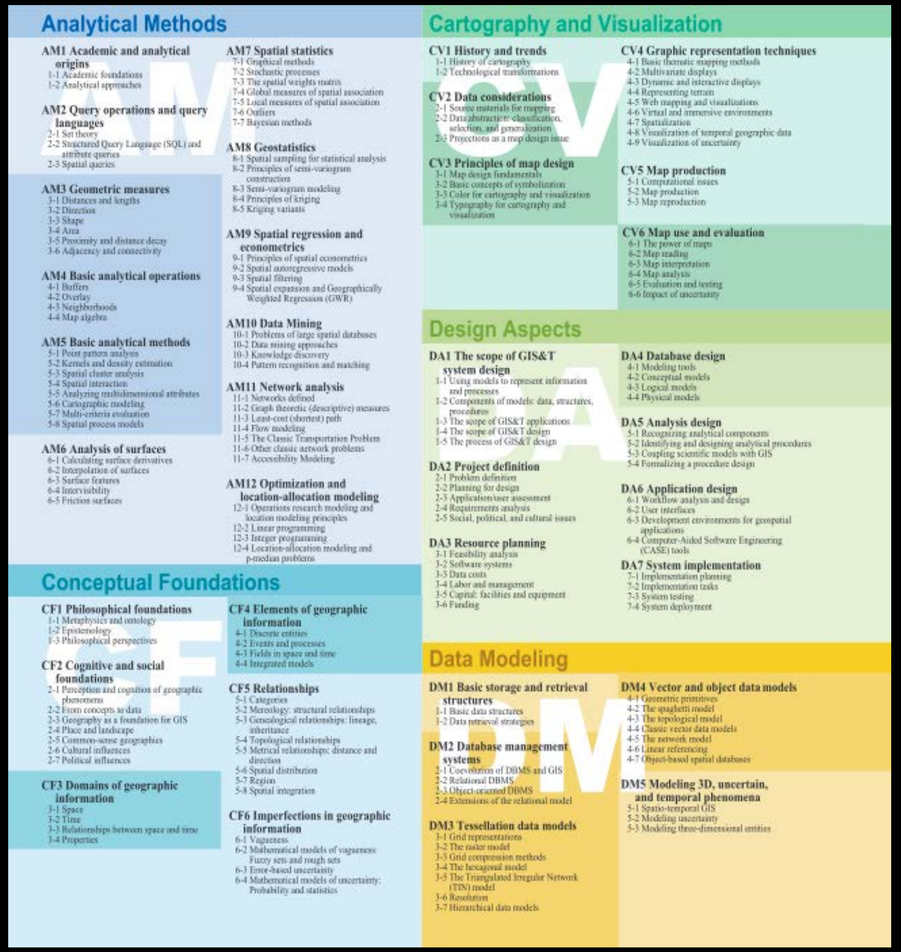
  Engage stakeholders in very remote areas, including many who strongly disagree with current land tenure and management

Questions from Practice

- 1) Which social and technical methods need to be developed to support routine geodesign use and updating of "best available science"?
- 2) How can ecosystem services be fully accounted for within a geodesign framework (positive impacts minimizing and mitigating negative ones)?
- 3) How can "robust decision-making" (plans evaluated against multiple contextual scenarios) be integrated into conventional planning ?

Precedent: GIS&T BoK

- UCGIS Body of Knowledge -
- Comprehensive Chart



Analytical Methods

AM1 Academic and analytical origins
1-1 Academic foundations
1-2 Analytical approaches

AM2 Query operations and query languages
2-1 Set theory
2-2 Structured Query Language (SQL) and attribute queries
2-3 Spatial queries

AM3 Geometric measures
3-1 Distances and lengths
3-2 Direction
3-3 Shape
3-4 Area
3-5 Proximity and distance decay
3-6 Adjacency and connectivity

AM4 Basic analytical operations
4-1 Buffers
4-2 Overlay
4-3 Neighborhoods
4-4 Map algebra

AM5 Basic analytical methods
5-1 Point pattern analysis
5-2 Kernels and density estimation
5-3 Spatial cluster analysis
5-4 Spatial interaction
5-5 Analyzing multidimensional attributes
5-6 Cartographic modeling
5-7 Multi-criteria evaluation
5-8 Spatial process models

AM6 Analysis of surfaces
6-1 Calculating surface derivatives
6-2 Interpolation of surfaces
6-3 Surface features
6-4 Intervisibility
6-5 Friction surfaces

AM7 Spatial statistics
7-1 Graphical methods
7-2 Stochastic processes
7-3 The spatial weights matrix
7-4 Global measures of spatial association
7-5 Local measures of spatial association
7-6 Outliers
7-7 Bayesian methods

AM8 Geostatistics
8-1 Spatial sampling for statistical analysis
8-2 Principles of semi-variogram construction
8-3 Semi-variogram modeling
8-4 Principles of kriging
8-5 Kriging variants

AM9 Spatial regression and econometrics
9-1 Principles of spatial econometrics
9-2 Spatial autoregressive models
9-3 Spatial filtering
9-4 Spatial expansion and Geographically Weighted Regression (GWR)

AM10 Data Mining
10-1 Problems of large spatial databases
10-2 Data mining approaches
10-3 Knowledge discovery
10-4 Pattern recognition and matching

AM11 Network analysis
11-1 Networks defined
11-2 Graph theoretic (descriptive) measures
11-3 Least-cost (shortest) path
11-4 Flow modeling
11-5 The Classic Transportation Problem
11-6 Other classic network problems
11-7 Accessibility Modeling

AM12 Optimization and location-allocation modeling
12-1 Operations research modeling and location modeling principles
12-2 Linear programming
12-3 Integer programming
12-4 Location-allocation modeling and p-median problems

Conceptual Foundations

CF1 Philosophical foundations
1-1 Metaphysics and ontology
1-2 Epistemology
1-3 Philosophical perspectives

CF2 Cognitive and social foundations
2-1 Perception and cognition of geographic phenomena
2-2 From concepts to data
2-3 Geography as a foundation for GIS
2-4 Place and landscape
2-5 Common-sense geographies
2-6 Cultural influences
2-7 Political influences

CF3 Domains of geographic information
3-1 Space
3-2 Time
3-3 Relationships between space and time
3-4 Properties

CF4 Elements of geographic information
4-1 Discrete entities
4-2 Events and processes
4-3 Fields in space and time
4-4 Integrated models

CF5 Relationships
5-1 Categories
5-2 Mereology: structural relationships
5-3 Genealogical relationships: lineage, inheritance
5-4 Topological relationships
5-5 Metrical relationships: distance and direction
5-6 Spatial distribution
5-7 Region
5-8 Spatial integration

CF6 Imperfections in geographic information
6-1 Vagueness
6-2 Mathematical models of vagueness: Fuzzy sets and rough sets
6-3 Error-based uncertainty
6-4 Mathematical models of uncertainty: Probability and statistics

Cartography and Visualization

CV1 History and trends
1-1 History of cartography
1-2 Technological transformations

CV2 Data considerations
2-1 Source materials for mapping
2-2 Data abstraction: classification, selection, and generalization
2-3 Projections as a map design issue

CV3 Principles of map design
3-1 Map design fundamentals
3-2 Basic concepts of symbolization
3-3 Color for cartography and visualization
3-4 Typography for cartography and visualization

CV4 Graphic representation techniques
4-1 Basic thematic mapping methods
4-2 Multivariate displays
4-3 Dynamic and interactive displays
4-4 Representing terrain
4-5 Web mapping and visualizations
4-6 Virtual and immersive environments
4-7 Spatialization
4-8 Visualization of temporal geographic data
4-9 Visualization of uncertainty

CV5 Map production
5-1 Computational issues
5-2 Map production
5-3 Map reproduction

CV6 Map use and evaluation
6-1 The power of maps
6-2 Map reading
6-3 Map interpretation
6-4 Map analysis
6-5 Evaluation and testing
6-6 Impact of uncertainty

Design Aspects

DA1 The scope of GIS&T system design
1-1 Using models to represent information and processes
1-2 Components of models: data, structures, procedures
1-3 The scope of GIS&T applications
1-4 The scope of GIS&T design
1-5 The process of GIS&T design

DA2 Project definition
2-1 Problem definition
2-2 Planning for design
2-3 Application/user assessment
2-4 Requirements analysis
2-5 Social, political, and cultural issues

DA3 Resource planning
3-1 Feasibility analysis
3-2 Software systems
3-3 Data costs
3-4 Labor and management
3-5 Capital: facilities and equipment
3-6 Funding

DA4 Database design
4-1 Modeling tools
4-2 Conceptual models
4-3 Logical models
4-4 Physical models

DA5 Analysis design
5-1 Recognizing analytical components
5-2 Identifying and designing analytical procedures
5-3 Coupling scientific models with GIS
5-4 Formalizing a procedure design

DA6 Application design
6-1 Workflow analysis and design
6-2 User interfaces
6-3 Development environments for geospatial applications
6-4 Computer-Aided Software Engineering (CASE) tools

DA7 System implementation
7-1 Implementation planning
7-2 Implementation tasks
7-3 System testing
7-4 System deployment

Data Modeling

DM1 Basic storage and retrieval structures
1-1 Basic data structures
1-2 Data retrieval strategies

DM2 Database management systems
2-1 Coevolution of DBMS and GIS
2-2 Relational DBMS
2-3 Object-oriented DBMS
2-4 Extensions of the relational model

DM3 Tessellation data models
3-1 Grid representations
3-2 The raster model
3-3 Grid compression methods
3-4 The hexagonal model
3-5 The Triangulated Irregular Network (TIN) model
3-6 Resolution
3-7 Hierarchical data models

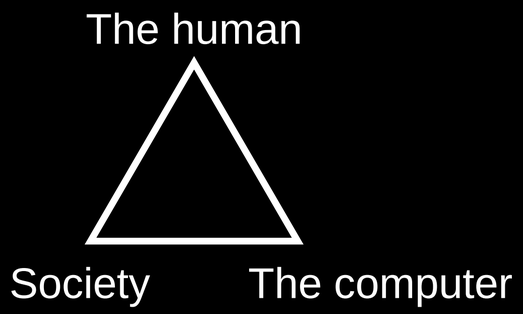
DM4 Vector and object data models
4-1 Geometric primitives
4-2 The spaghetti model
4-3 The topological model
4-4 Classic vector data models
4-5 The network model
4-6 Linear referencing
4-7 Object-based spatial databases

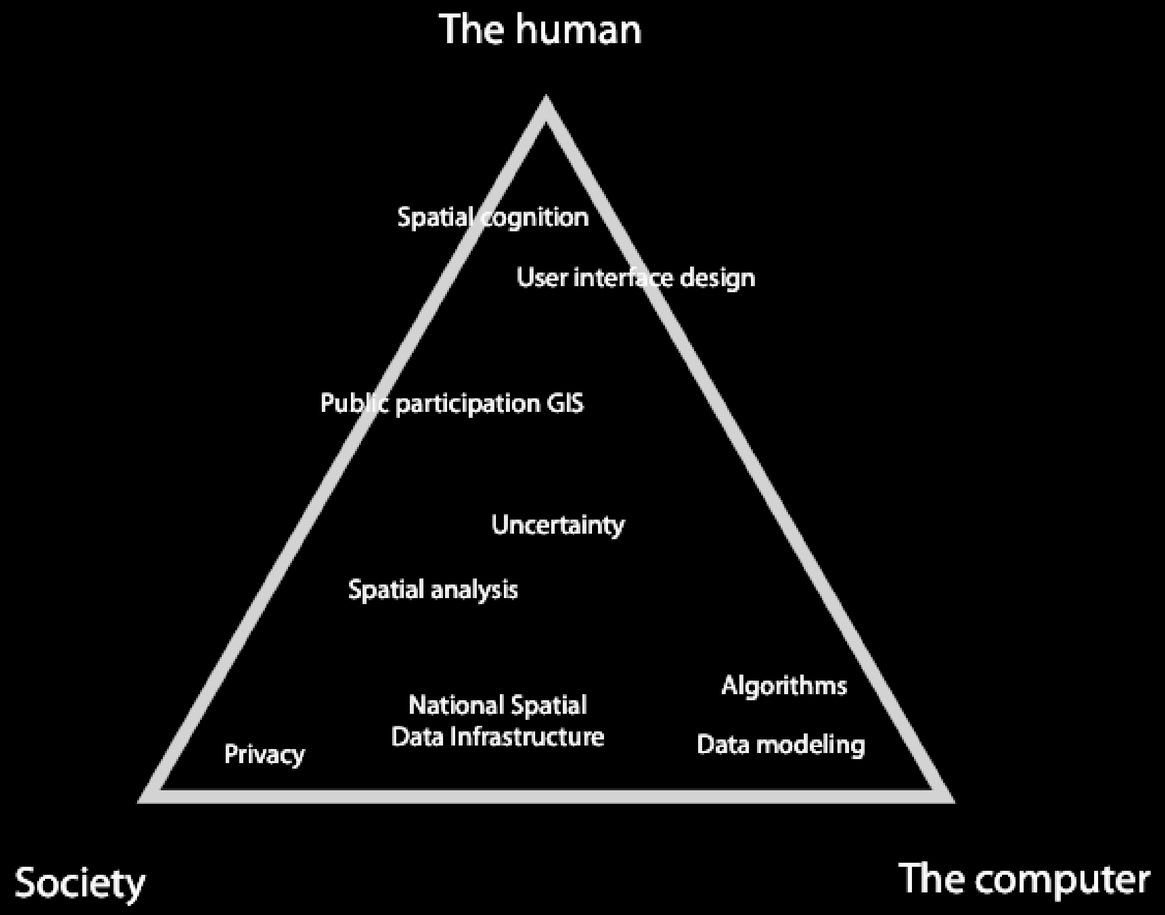
DM5 Modeling 3D, uncertain, and temporal phenomena
5-1 Spatio-temporal GIS
5-2 Modeling uncertainty
5-3 Modeling three-dimensional entities

- Over 100 + topics! Perhaps too many categories…

Precedent: NCGIA

- Consider the NCGIA 3-point triangle
- 'People, Society, Computers' -
- robust, but simple (& geography implicit),

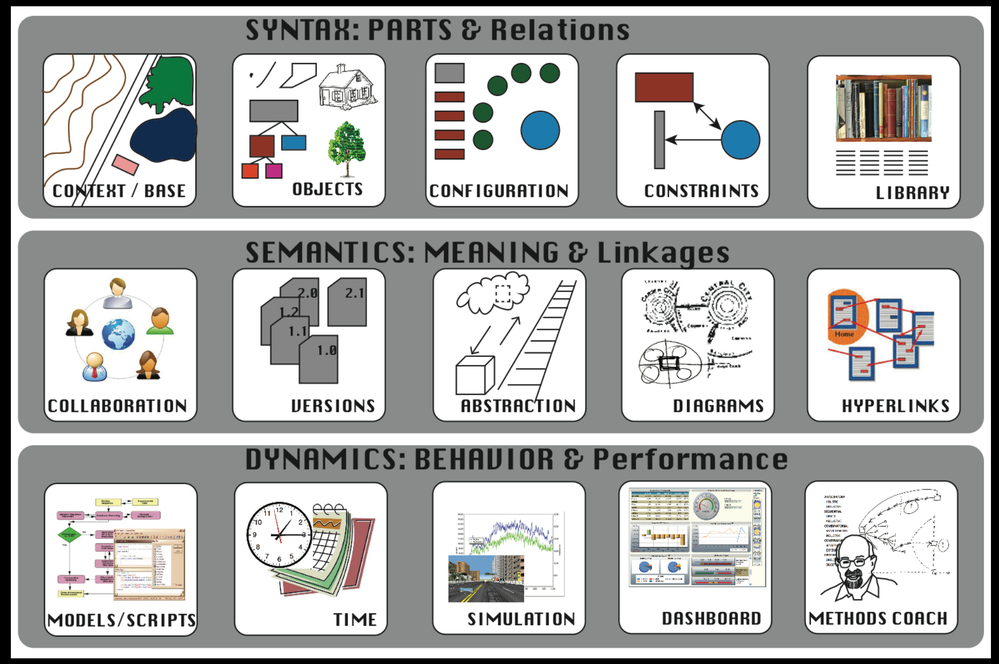




- And … no design! Perhaps too few categories…

Precedent: Ervin’s 15-part System

- perhaps look at Ervin's 15 part 'system / toolbox'
- ... Design topics included (e.g. constraints, diagrams, simulation...)
- ... But perhaps 15 is still too many categories...



Precedent: Miller’s 9-point List

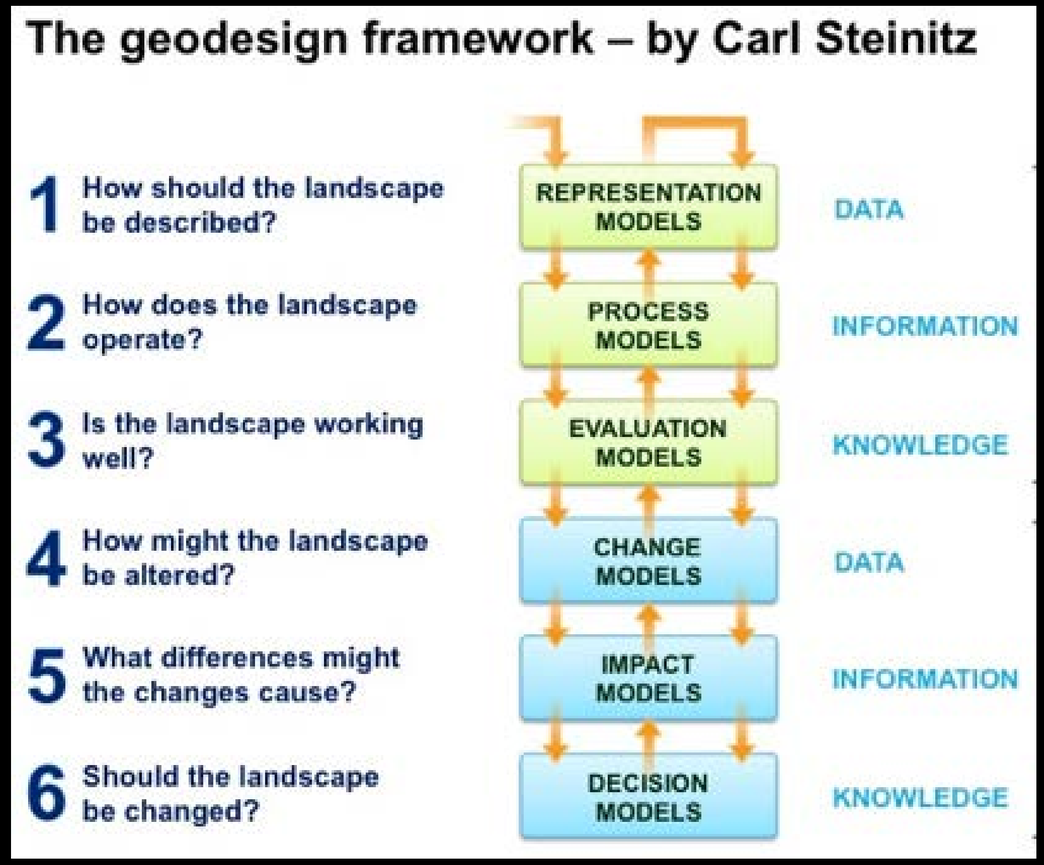
- Good List but somewhat ‘instrumental’ focus…

- **Operational frameworks**
- **Data models**
- **Creation and modification tools**
- **Inference engines**
- **Geo processing tools**
- **Feedback displays and dashboards**
- **Scenario management tools**
- **Collaboration tools**
- **Interoperability tools**

Miller, 2012.
Introducing Geodesign:The Concept.
White paper. ESRI Press.

Precedent: Steinitz's 6-part Framework

- Structuring a research agenda on the framework
- What if each step generates research questions?
- Advantage: well known and procedurally strong
- Challenge: tacit on 'who', scale, issues

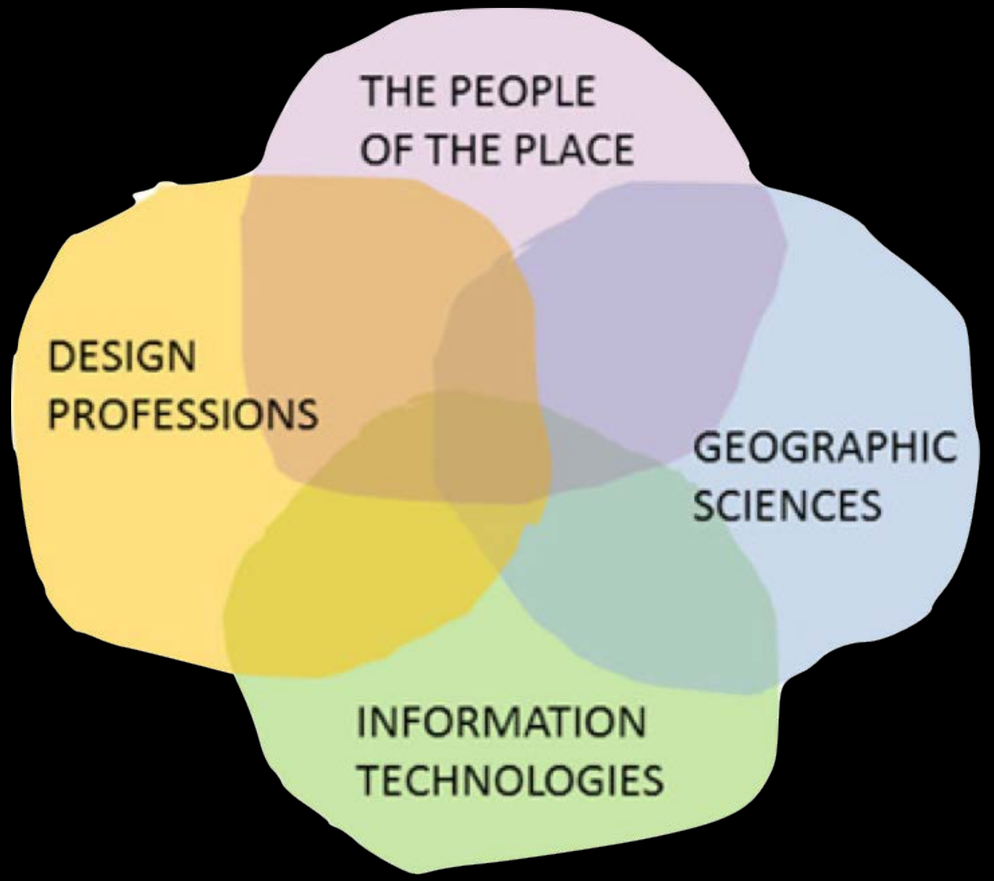


Precedent: Steinitz's 4-pole Venn Diagram

- Useful - Broad, Spatial

  Introduces Design Explicitly…

- Connects to Disciplines



Steinitz's Venn Diagram @ NAU

- Maps Curriculum into 4 poles…

GSP Core Course Key:
130: Mapping the World
150: Physical Geography
201: Community, Planning & Change
206: Public Participation & Comm.
240 or 241: World Geography West/East
303: Community Design & Preservation
331: GIS Foundations I: Map Design
371: The Urban Realm
375W: Community & Global Analysis
405C or 480C: Capstone Professional Project

Source: *Paradis, T. 2011 Adopted from Steinitz, C., 2011 GeoDesign Summit Presentation.*

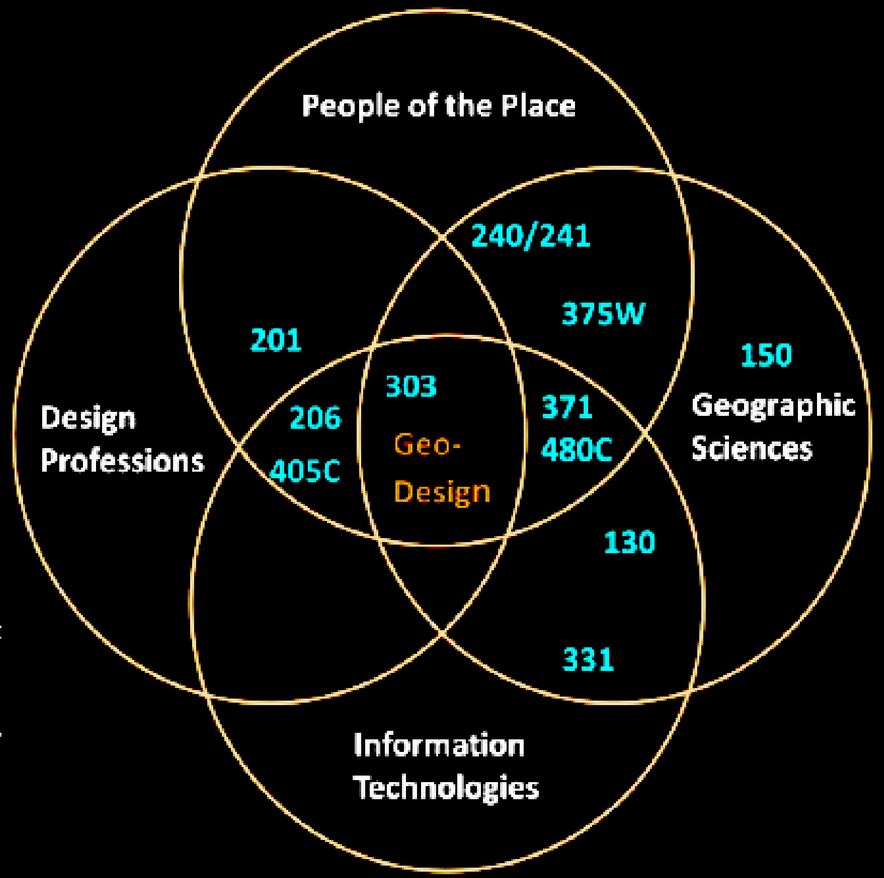
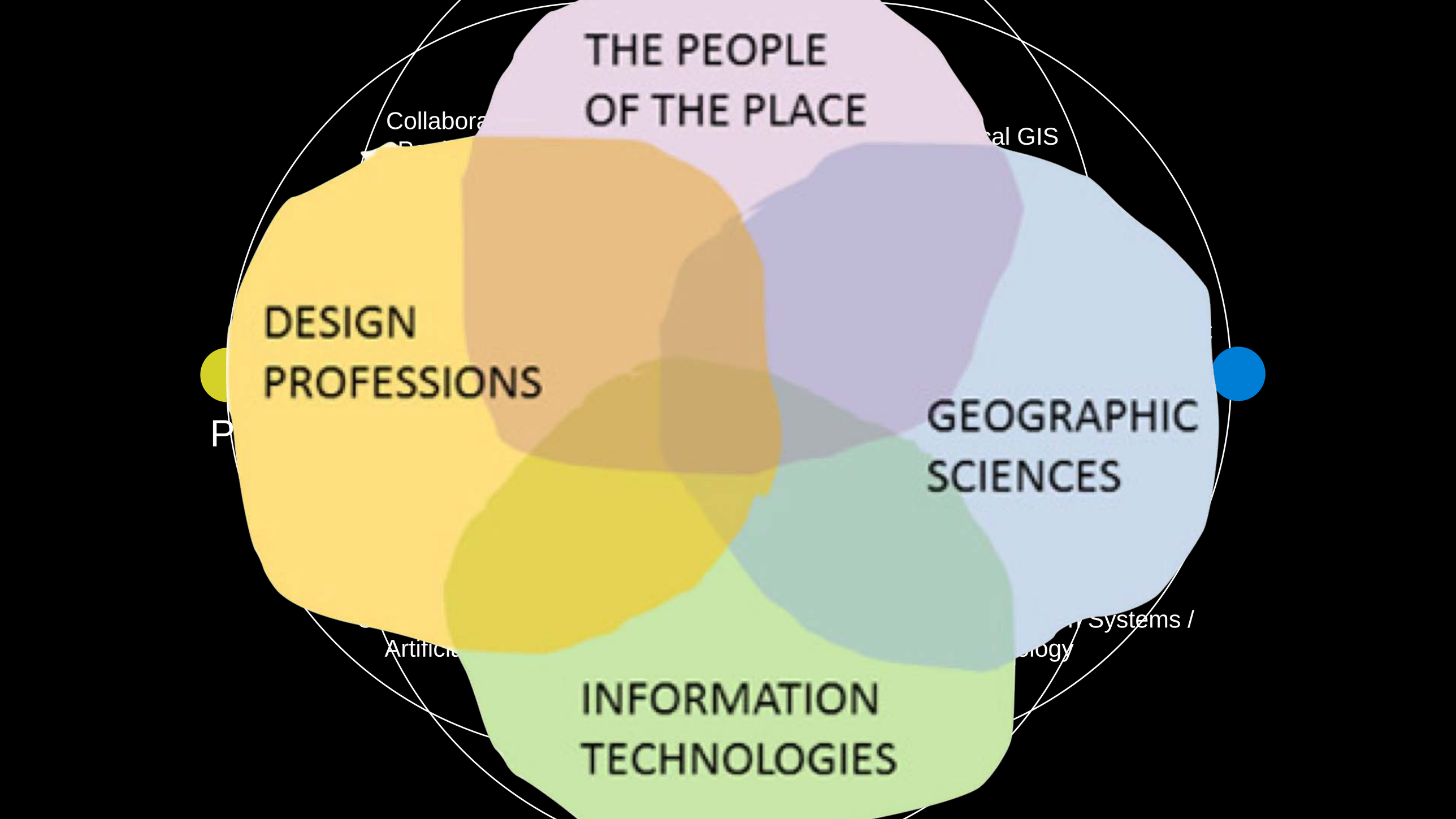
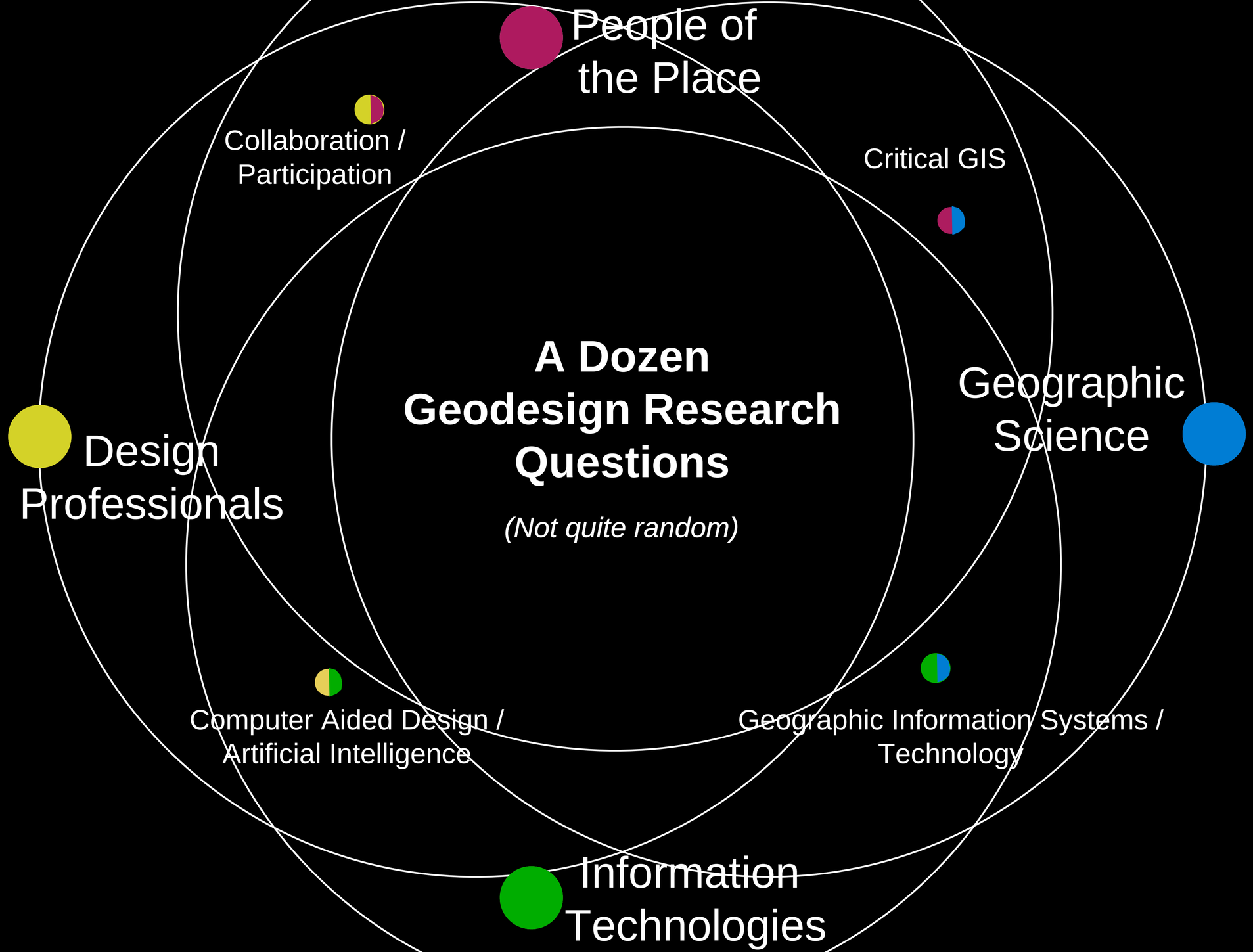


Figure 3. The Steinitz Geodesign Framework with GSP course numbers embedded. Course location is based on a qualitative estimate of their weighting toward one or more geodesign areas. Source: Tom Paradis, Mark Manone.


THE PEOPLE
OF THE PLACE
DESIGN
PROFESSIONS
GEOGRAPHIC
SCIENCES
INFORMATION
TECHNOLOGIES


People of the Place
Collaboration / Participation
Critical GIS
A Dozen Geodesign Research Questions
(Not quite random)
Design Professionals
Geographic Science
Computer Aided Design / Artificial Intelligence
Geographic Information Systems / Technology
Information Technologies

What are some examples of projects - real or imagined - that clearly and convincingly serve to define what Geodesign is and, importantly, what it isn't? — Dana Tomlin

What are the relationships between "problem type/size/scale" and effective "ways of designing"? How complex do models need to be in order to properly inform and influence geodesign decisions? — Carl Steinitz

How can/should 2D planning tools and 3D simulation tools interact? What are desirable attributes of 'geodesign dashboards'? What tools/techniques are required for productive multi-party web-enabled collaboration in geodesign? — Eric Wittner & Bill Miller

Which social and technical methods need to be developed to support routine geodesign use and updating of "best available science"? Mike Flaxman

What does the doing of 'critical geodesign' mean? — Matt Wilson

To what extent should (or would) geodesign approaches and practices benefit from (as well as shape) innovative smart environments in order to improve or facilitate citizen engagement? — Stephane Roche

How is geodesign different from "traditional design" methods? Does the notion of "primary generator" have relevance to (or meaning in the context of) geodesign? What would be the best use(s) of AI in geodesign? — Allan Shearer

What system architecture(s) can form the basis of an end-to-end and top-to-bottom geodesign environment to address complex sustainable systems (decision) interventions that are theoretically sound and practically useful? — Timothy Nyerges

How can GIS technology be extended to include/cover all of the elements of a geodesign ontology (including e.g. dynamics, interactions, affordances, and especially "purpose" — answers to "why?" questions)? — Mike Goodchild

What role might geodesign play in addressing the "grand challenges" of our time and how might these tools and methods be more widely used in order to deal with those challenges? — Tom Fisher

What distinguishes geodesign from similar processes? — Kelleann Foster

What are the roles of diagrams in geodesign and how might they be digitally represented and computed with? — Stephen Ervin

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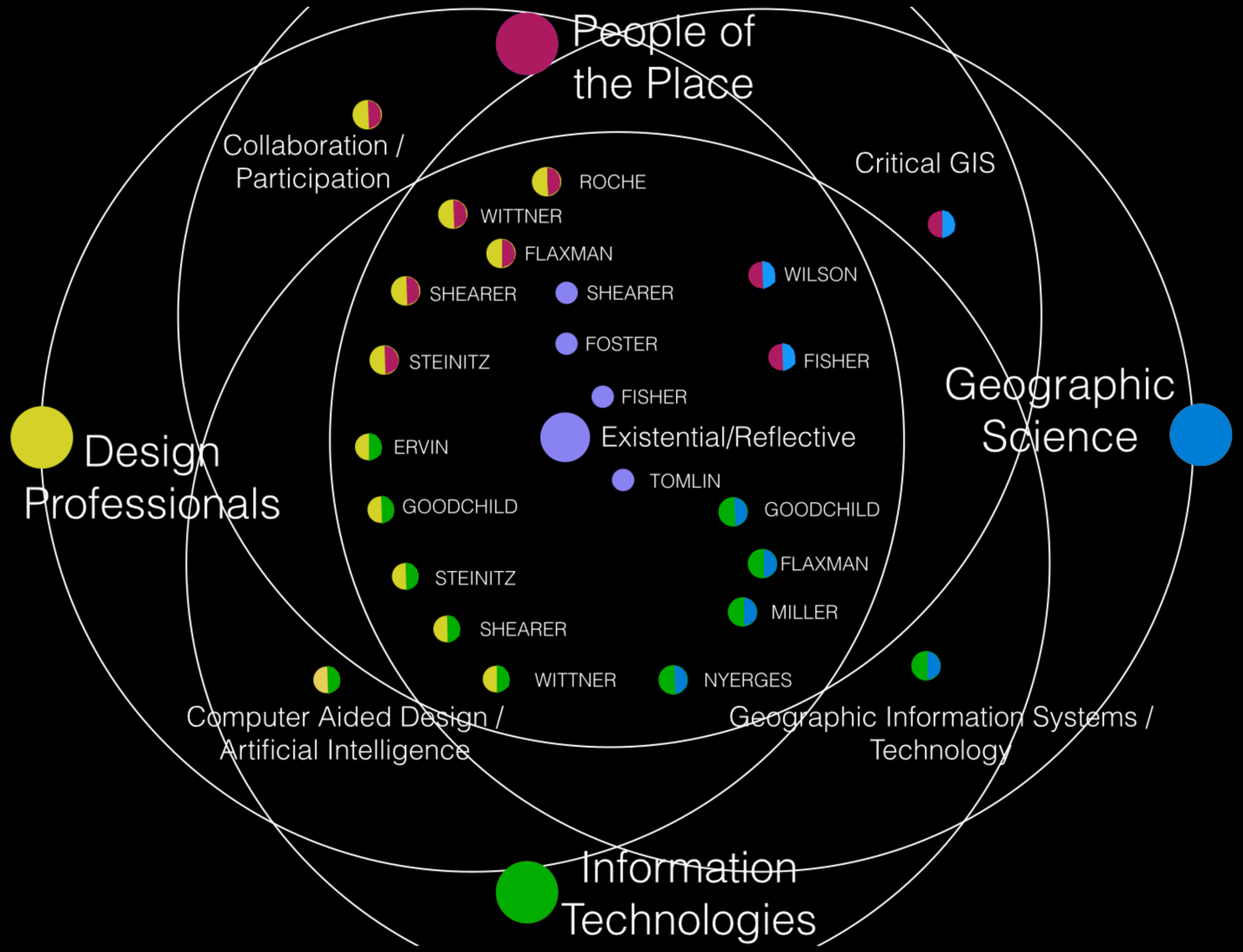
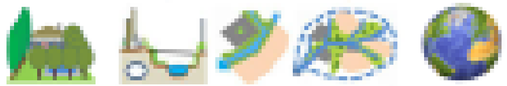
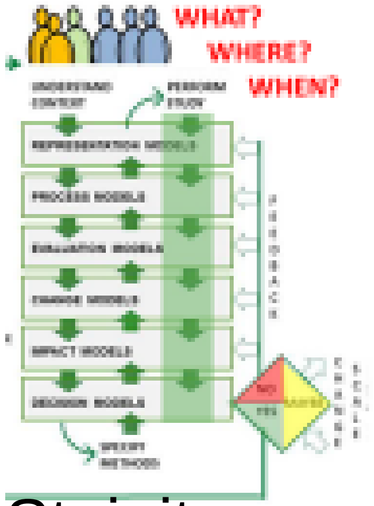
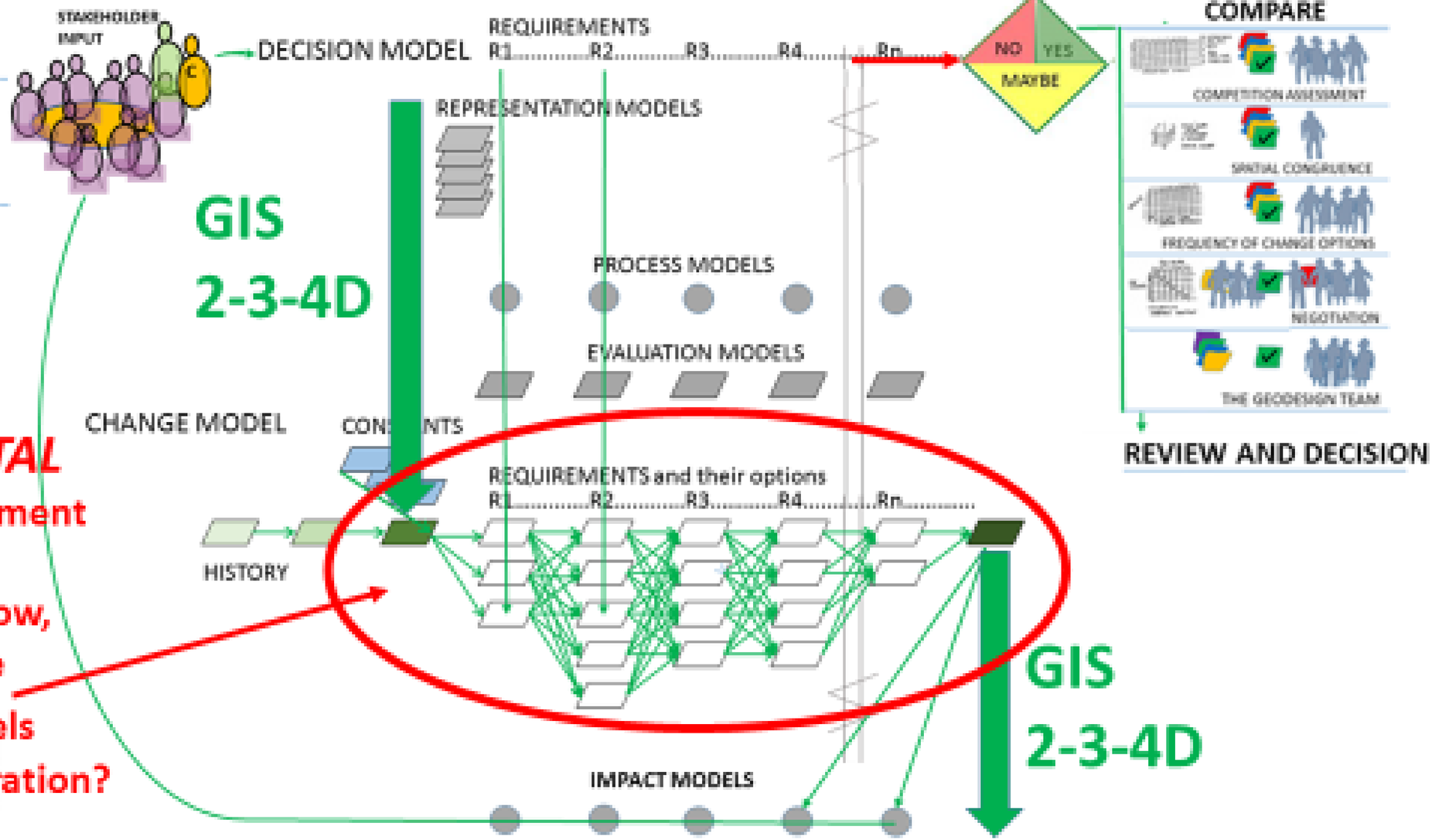
Map of Geodesign Research Space



WHY? HOW? WHAT? WHERE? WHEN?







Carl Steinitz:

What kinds of *DIGITAL* information-management support are needed for geodesign workflow, and especially for the the CHANGE models in geodesign collaboration?

Observation 1:

DESIGN

- Really, it’s the DESIGN component that’s new in geodesign, and that should drive a big part of the research enterprise
- (as we benefit from all the other ongoing research in GIS&T, AI,ITC, social computing, etc….)
- but ‘design research’ is nebulous, and hard!

Observation 2:

Spatial Scenarios

- Both sciences and design are taking place in a changing world
- Spatial scenario simulations represent the start of a “lingua franca”, understood (differently) by all parties
- However, participatory generation, management and sharing of large number of separately-conceived scenarios is still challenging

Observation 3:

Impact Assessment

- Rapid design-time geospatial impact assessment is a stated goal of geodesign
- However, we need empirical research to validate this assumption, and Steinitz' work suggest this varies by scale and method

Observation 4:

Biomimicry & Ecosystem Services

- Janine Benyus' '14 keynote challenged us to start design with a very high standard (nature)
- 'Ecosystem services' provide a framework for quantifying triple-bottom-line impacts
- Design tools which credit positive ES contributions of good design fit geodesign well, but are very underdeveloped

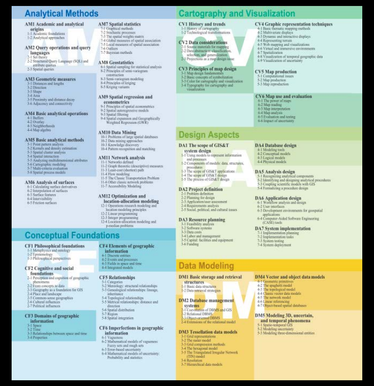
Observation 5:

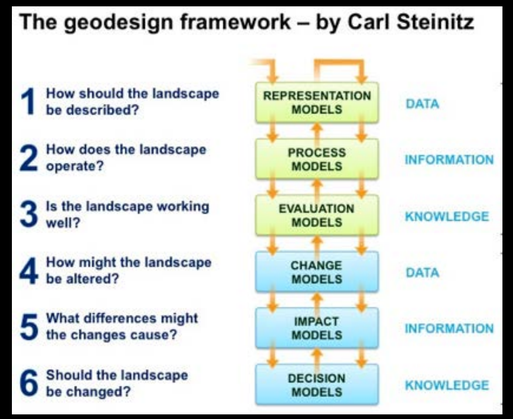
Interoperability is Key!

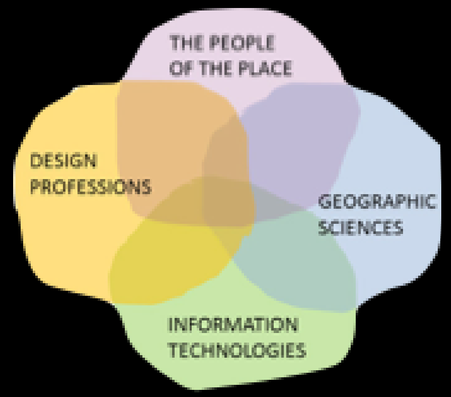
- A key component of geodesign is the intersection -> interaction -> **INTEROPERABILITY** between four domains; so a key research topic is interoperability — between people, systems, disciplines, models, etc — This requires shared language, data models, …

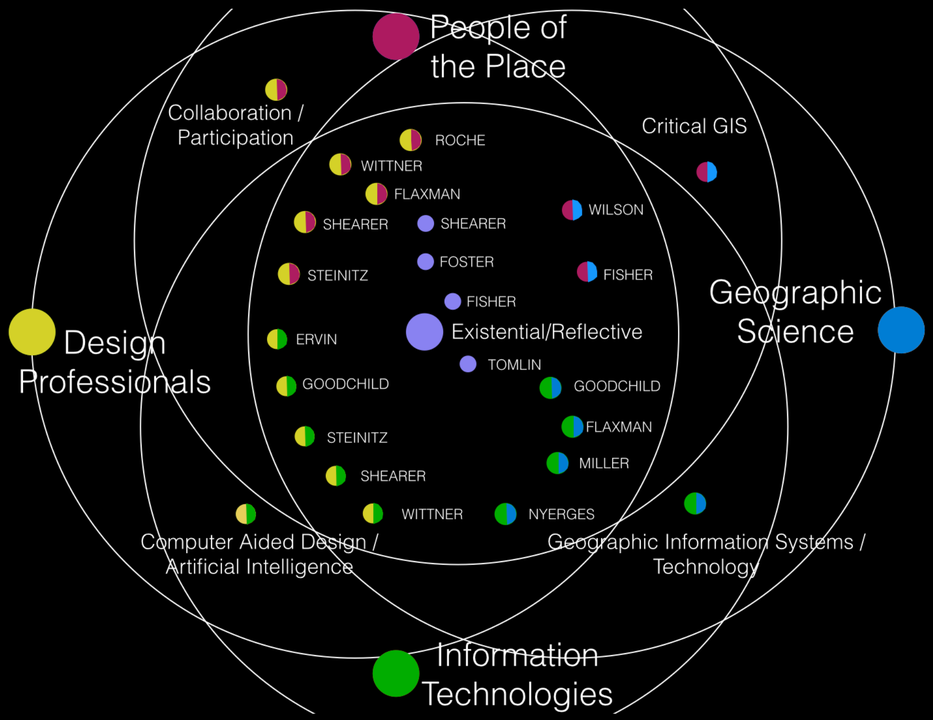
Conclusions

- Community of researchers/practicioners needed to push research along…Various precedents to guide - new modes/forms of research indicated?



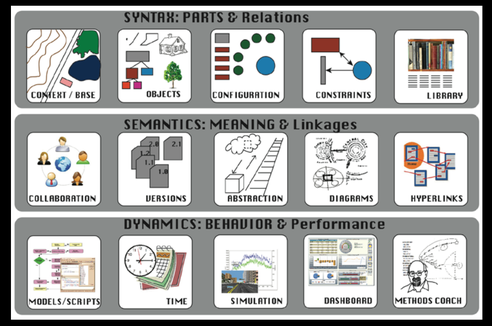






The human

Society The computer



Opportunities to Engage

- Spatial Decision Support Consortium (~40+ member group) actively discussing collaborative opportunities and upcoming proposals (see Tim Nyerges or Naicong)
- Geodesign Research Network Google Plus Group:

http://snipurl.com/geodesignresearch

- Or tweet using #geodesignresearch