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NAVAL POSTGRADUATE SCHOOL

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DYSTOPIA: A VIRTUAL ENVIRONMENT FOR EDUCATION, TRAINING, AND EXERCISES

by

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14. ABSTRACT

The growing complexity of security problems is challenging traditional paradigms for education and research. A key recognition for learning about how to manage this complexity is the importance of the context for the situations and the decisions that need to be made. This report describes a particular effort to develop a fictitious place called "Dystopia" used to create a realistic context for classroom discussions, tabletop exercises, simulation modeling, and other educational activities. We provide historical background on the motivation and genesis of Dystopia, along with details of its original implementation. Additionally, we describe more recent efforts to develop data for simulation of critical infrastructure systems within Dystopia, and we articulate several opportunities for the use of Dystopia in the future.

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Abstract

The growing complexity of security problems is challenging traditional paradigms for education and research. A key recognition for learning about how to manage this complexity is the importance of the context for the situations and the decisions that need to be made. This report describes a particular effort to develop a fictitious place called "Dystopia" used to create a realistic context for classroom discussions, tabletop exercises, simulation modeling, and other educational activities. We provide historical background on the motivation and genesis of Dystopia, along with details of its original implementation. Additionally, we describe more recent efforts to develop data for simulation of critical infrastructure systems within Dystopia, and we articulate several opportunities for the use of Dystopia in the future.

1 Introduction

The growing complexity of security problems, both at home and abroad, is challenging traditional paradigms for education and research. For practitioners who ultimately need to operate in security-related missions, it's not enough simply to read about these problems.

It is important that our next generation of leaders not only remember and understand the lessons of past security incidents, but also can apply this knowledge to new situations, draw connections to other experiences, evaluate new novel situations, and ultimately create new knowledge for dealing with emergent challenges. This progression is consistent with classic theories of learning (e.g., Bloom et al. 1956) and modern adaptations (e.g., Krathwohl and Anderson 2001).

There has been a considerable growth in the development and dissemination of curricula devoted to national security issues (e.g., see the review by Stewart and Vocino 2013), with considerable attention paid to the changing needs of this emerging discipline (Bellavita and Gordon 2006; Kiltz 2011) and the different educational models for delivery (Polson et al. 2010; Pelfrey and Kelley 2013).

Across these different programs, a key recognition for learning about how to manage the complexity of emerging homeland security problems is the importance of the *context* for the situations and the decisions that need to be made. That context is in part the result of the richness of the real world. In fact, it is often the case that expert decision makers are unable to articulate which stimuli in the real world were necessary to a decision they made (Klein 1999). What is needed is a rich world with all its complexities in which to explore and practice. But using the real world is problematic because the data needed to support decision making is the cause of security issues in itself. Therefore, what is needed is a virtual world that contains as much of the richness of the real world that we can possibly attain, without exposing sensitive real world data.

This report describes a particular effort by the Center for Homeland Defense and Security (CHDS) at the Naval Postgraduate School (NPS) to develop a fictitious place called "Dystopia" used to create a realistic context for classroom discussions, tabletop exercises, simulation modeling, and other educational activities. We provide historical background on the motivation and genesis of Dystopia, along with details of its original implementa-

tion. Additionally, we describe more recent efforts to develop data for simulation of critical infrastructure systems within Dystopia, and we articulate several remaining opportunities for the use of Dystopia in the future.

2 Motivation & Genesis

The Center for Homeland Defense and Security (CHDS) at the Naval Postgraduate School (NPS) has offered an innovative curriculum for more than 15 years (see www.chds.us).

When the Center for Homeland Defense and Security (CHDS) was founded in 2003, post-9/11, one of the initial motivations was to avoid creating a conventional graduate degree program with typical courses, assignments, and learning outcomes. Instead, what was desired was to explore a new way of teaching and learning. One of the key enablers to this approach was the use of games and simulations under the theory that interactive, student-driven learning was superior to instructor-led learning. This is often referred to as "constructivism" in the literature (https://www.learning-theories.com/constructivism.html).

To this end, a virtual world called "San Luis Rey" (named after the fictional town in Thornton Wilder's novel with the notorious bridge) was developed by the Teleologic Learning Company, Inc. (TLC) under contract to the Naval Postgraduate School. A number of scenarios were created for several courses in the program where San Luis Rey provided the context for the scenario. For example, for an exercise scenario concerning Posse Comitatus (the limits of the federal government to act in domestic affairs), a large terrorist event or disaster might occur in San Luis Rey to which the federal government responds on (or without) request from the local San Luis Rey government. The virtual world would supply places, maps, people (including names of key characters and a short biography) and any other context necessary to support the exercise.

2.1 Design Challenges

While San Luis Rey was effective for what it was intended to do, it was also severely limited. First, San Luis Rey was developed by a contractor that viewed it as a product that it wanted to "own" and control. Because of that, San Luis Rey could only grow as needed for the CHDS program or other customers of TLC. Second, San Luis Rey was developed in way that maintained only surface credibility. Elements of the virtual world were added only as

needed. There was no overall design or deep structure to how it was constructed, therefore, it was easy to find anomalies that were symptoms of how it was built. When we began to look into using San Luis Rey to support Critical Infrastructure (CI) exercises, we realized it would be insufficient for our needs, but the idea of a fictional virtual world was appealing for a number of reasons.

1. Critical infrastructure assessments are inherently sensitive. Conducting them in a fictional virtual world is appealing because we can publish results and share with anyone. But this only works if the virtual world has enough fidelity that our assessments are accurate and meaningful. Therefore, we needed our virtual world to be capable of a much higher level of physical realism.
2. We needed to be able to share. We strongly believe that one of the key impediments that is limiting research in critical infrastructure modeling and assessment is our inability to share results. We need to be able to conduct an analysis and then have another researcher conduct the same analysis using the same data so that we can compare results.
3. Lastly, the community can build the world. As different users have new needs, they will build out the environment to support their studies. Then all subsequent users will have the use of those new features and can build them out further as needed.

Dystopia was initiated in 2006 to address these issues. Dystopia is intended to be a stand alone product, but it is not an application in and of itself. We have found that one of the most common misconceptions is that Dystopia is a game or simulation. It is not. It is merely structured data. More specifically, Dystopia is a collection of geospecific and meta data that creates a robust, deep virtual environment on which exercises, games, and analyses can be built. Dystopia must be embedded in an application that contains game logic, exercise rules, or analysis procedures. It can also be used for tabletop or other live exercises that do not use software but rather impose rules explicitly thus using the electronic viewing and searching products of Dystopia for efficiency.

2.2 Original Design Requirements

The objective of Dystopia is to provide a virtual place that can be used to support any number of homeland defense and security exercises, games, and analyses as required. The

desired end product has the following characteristics:

1. It is entirely Unclassified. All data within Dystopia is fictitious including people, places, and events. If a specific exercise or analysis wishes to add classified information (having to do with a procedure, for example) then that information must be controlled by that group and not shared as a common element of Dystopia.
2. It is an extremely robust and information-rich environment. The entire environment will eventually be built out. All street names, buildings, people, and places will be developed. All will be accessible either spatially through mapping products, or via their metadata.
3. It is physically realistic. Of course, as is the case with all models, physical perfection is unattainable, but the physical characteristics that affect analyses and exercises must retain enough fidelity to achieve the goals of the event. Ideally, fidelity is scalable so that for an exercise low fidelity may be all that is needed whereas for a CI analysis the highest fidelity is required.
4. It has a variety of 2D representations (maps), 3D representations (terrains, models), and metadata (Dystopedia) products. These will be described in more detail below.
5. It is persistent (selectively). As Dystopia is used for analyses and exercises, scenario specific data can be contained in a scenario layer which can retain a memory of past events, people, and places. The instructor may choose to reset the scenario to its initial conditions, or may choose to retain parts or all of a past exercise. If a major terrorist attack should occur in an exercise, that can be used as background information for a future exercise, or can be deleted for reuse. It can become a part of Dystopia "history". In other words, time need not be a constant in Dystopia.
6. It is easy to modify. Dystopia, like the real world, is a living, changing place where everything changes over time. Those changes need to be easy to execute and those changes must propagate throughout all Dystopia products easily. If a new building is placed in a specific location, maps of that area must be easily updated, the 3D representation must be updated, and the metadata for that location must be updated.
7. To facilitate ease of modification, there is one, archived master source for Dystopia data. Users of the data may make their own copies but there is one and only one master copy. Typical use would be to use the master as the core layer and then add scenario layers as needed (see figure below).

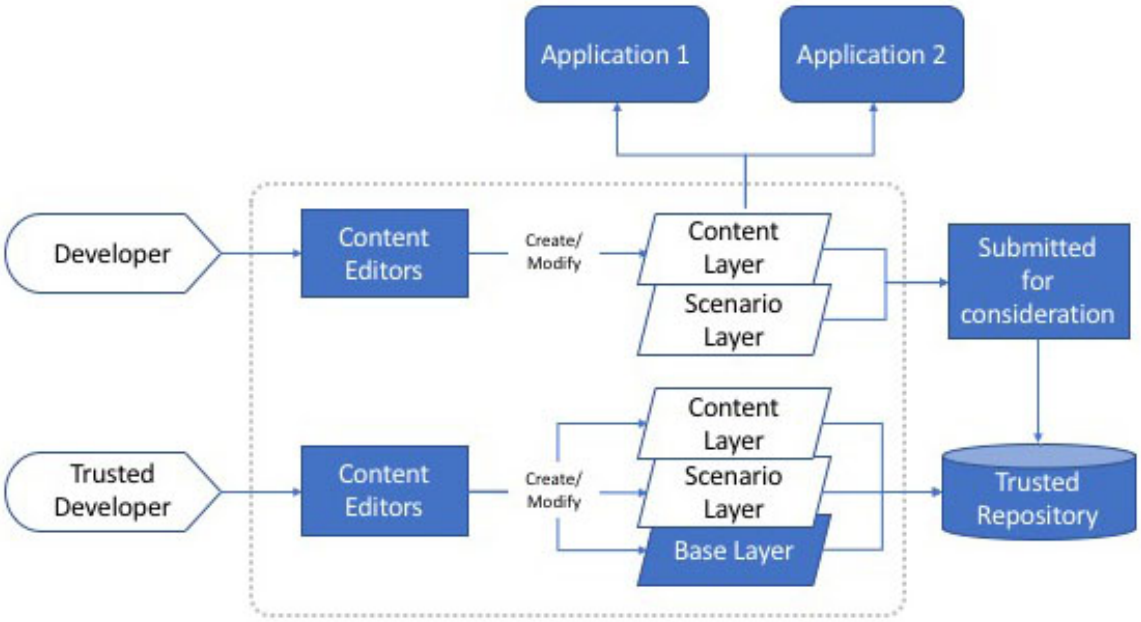

Figure 1. Conceptual schematic diagram for the original Dystopia implementation.

8. It is easy to share and to incorporate (as desired) shared changes. The model is of open source software where there is a team of trusted content developers, but any others can use it and extend it. The trusted team gets to decide which changes are adopted into the core product and which are not. Content can be easily moved from a scenario layer to the core layer, thus making a part of the master. Dystopia must be shareable without embedding it into an application.

2.3 Concept

The basic concept of how Dystopia was originally envisioned to be implemented was in data layers. To achieve the goals described in the previous section (see Figure 1), the original idea was to pattern Dystopia after open source software (OSS).

In OSS, there are *developers* who use the OSS product and who may write candidate code that adds features or fixes bugs in the main product. *Trusted developers* are the same as developers but they are considered part of the management team that manages the OSS product. They decide what source code is included in the OSS package and what is not. Therefore, code from developers is scrutinized before being included whereas trusted

developers may be less scrutinized before inclusion. The official distribution copy of the OSS product is held in a *trusted repository* which is distributed to users in source code, object, or executable form.

The original concept for Dystopia included *trusted developers* and *developers* who both have a similar roles to their OSS counterparts. Dystopia has a base layer upon which any number of additional layers can be added for whatever purpose is envisioned. These layers might be content-specific, such as road meshes, electric grid, topography, structures, or scenario-specific such as people, history, or other attributes not tied to geography or geographic locations. These are usually most useful in designing scenarios for exercises and games. It is advantageous to be conservative when deciding on a "theme" for a layer. It is better to have too many layers that must be merged than to have too few and have to separate them later.

The original concept also included *content editors* that trusted developers use to directly modify layers. There can be any number of content editors because the editor likely is specific to the type of layer it is creating or modifying. An editor for the power grid, for example, might have tools that ensure that the resulting grid is feasible. A transportation editor might do the same for roads and highways.

As noted above, changes made by a trusted developer may directly modify the core representation in the trusted repository. This does not mean that a developer who is not a trusted developer cannot have access to these tools. In fact the content editor for developers in the figure might be the same as the content editor for trusted developers, the difference being that developers create content for their specific scenario that will be used in their applications and that does not directly change the core Dystopia product, whereas trusted developers can change the core product without additional review. But because a goal is to allow developers to contribute to Dystopia, those new layers can be submitted for consideration for inclusion to the core Dystopia product.

2.4 Description

Dystopia is a small mini-continent with a full coastline. It is at least as large as a medium sized state since it needs to support multiple municipalities. As described above, Dystopia is constructed of layers of data. The base layer is the only layer that every user has in

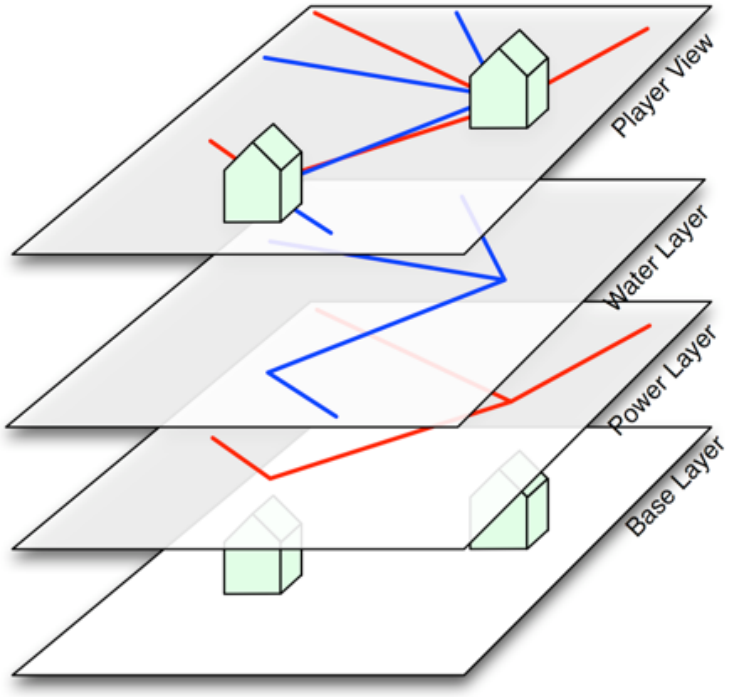

Figure 2. Content layers representing infrastructure networks.

common. There are then two types of layers that can be applied to "fork" the base Dystopia into whatever the end user desires; these are content layers and scenario layers.

Content layers are useful for data such as infrastructure networks or other comprehensive data sets that are not useful for every application. Therefore, the end user may wish to turn these off by not selecting that layer. In Figure 2, the base layer has only the two buildings on it. The end user has selected to present the power layer and the water layer to the player's view.

Scenario layers are for scenario specific data that is not in the base layer. This could include specific buildings, events, people, etc. that are needed for a scenario but are not assumed to be incorporated into any base layer.

Content and scenario layers override the base layer in a hierarchical fashion. Data in a layer that exists only in that layer simply is added to the base layer for presentation to the user. Data that replaces base layer content overrides it. In Figure 3, the base layer contains only the two green buildings. The scenario layer constructed by the end user replaces one

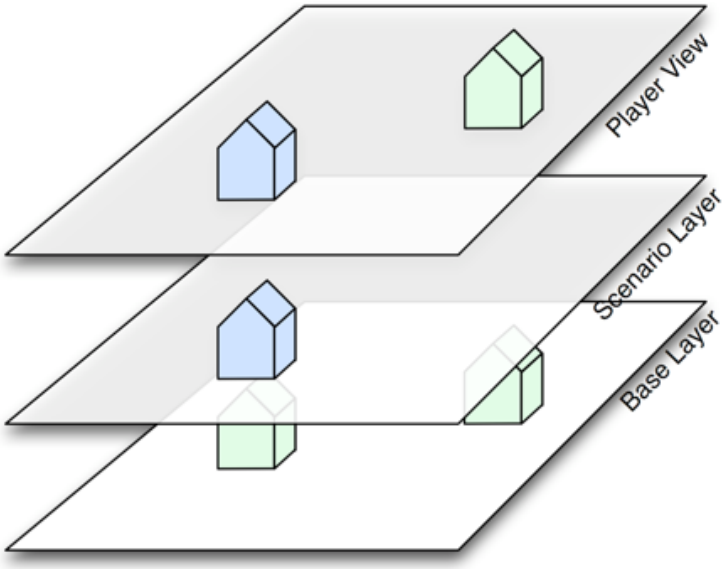

Figure 3. Scenario layers representing an override of base layer data.

of these with a blue building. The resulting player's view contains the one original green building and the new blue building from the scenario layer.

This same override behavior is true of meta data as well. If the base layer says that the Cape Hazard mayor is John Doe, an end user can create a scenario layer that overrides this to be Jane Doe without affecting other parts of Dystopia. The end user can also add scenario specific data in a scenario layer. If it was necessary to state that John Doe is a graduate of Farber University, that can be added to the Dystopedia entry for John Doe without affecting the other information about him.

2.5 Key Features

Dystopia is designed to support both two- and three-dimensional mapping products.

Two dimensional mapping products:

- Road Maps. Dystopia is intended to support both static (Figure 4 LEFT) and dynamic (Figure 4 RIGHT) road maps.
- City Maps. Dystopia is intended to support city maps showing different levels of detail (Figure 5).

- Mass Transit Maps. See Figure 6.
- University Maps. See Figure 7.
- Tourist Maps. See Figure 8.
- Topographical Maps. See Figure 9.
- Utility Maps. See Figure 10.
- Military Base Maps. See Figure 11.

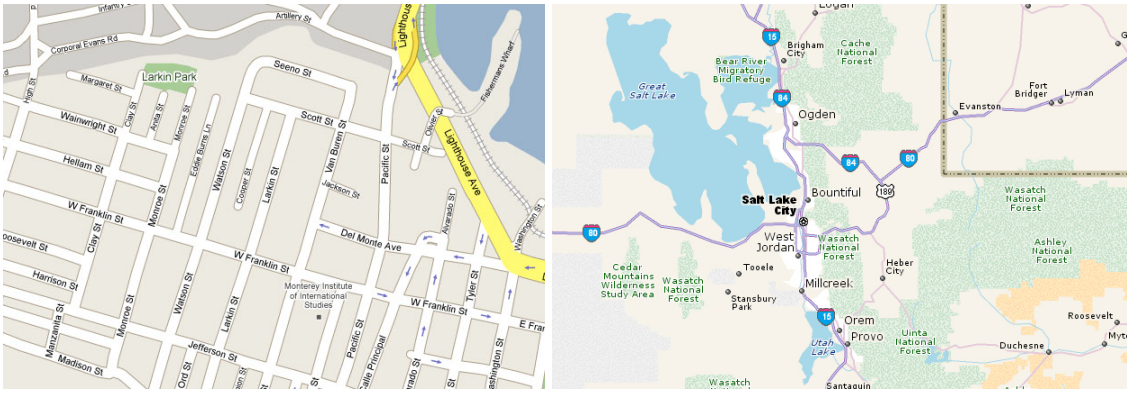

Figure 4. LEFT: Road maps (static). These are like Rand McNally maps or at a minimum, like a typical printed Google Map without an aerial view. These show only primary and secondary roads. RIGHT: Road maps (dynamic). This is a typical slip map like a Google Map.

Figure 5. City maps: Zoomed in to the downtown areas of the major cities in Dystopia, city maps are static, sometimes thematic maps showing detail of downtown retail, office, residential, and public areas. These maps show primary, secondary, and tertiary roads.

Figure 6. Mass transit maps: Thematic maps representing the bus routes, light rail, heavy passenger rail, and industrial rail routes.

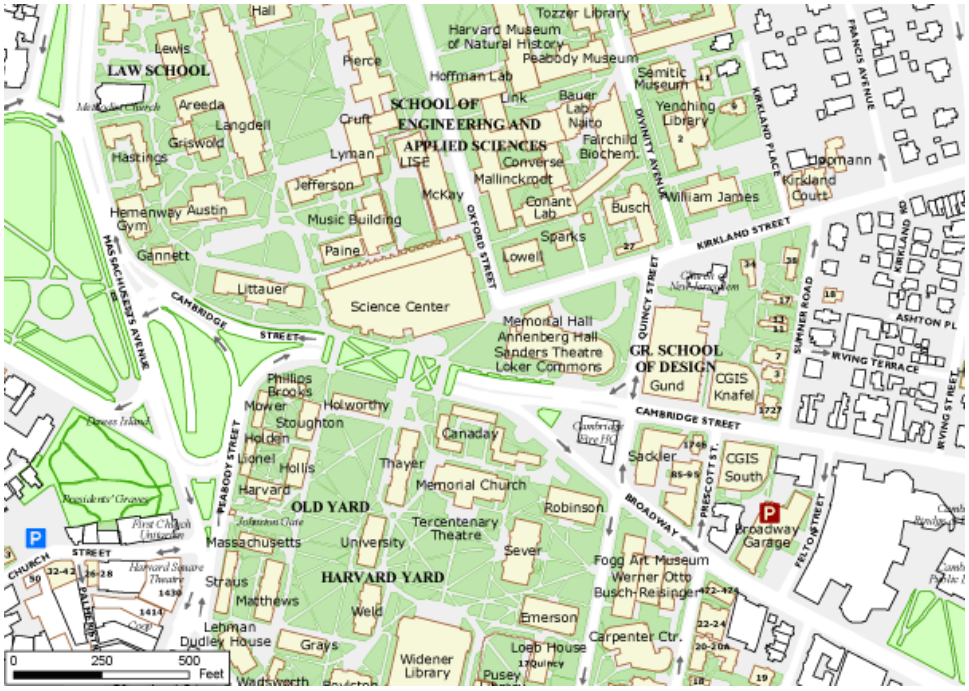

Figure 7. University map: A thematic maps of Farber University indicating each building, parking areas, stadiums, and areas of interest.

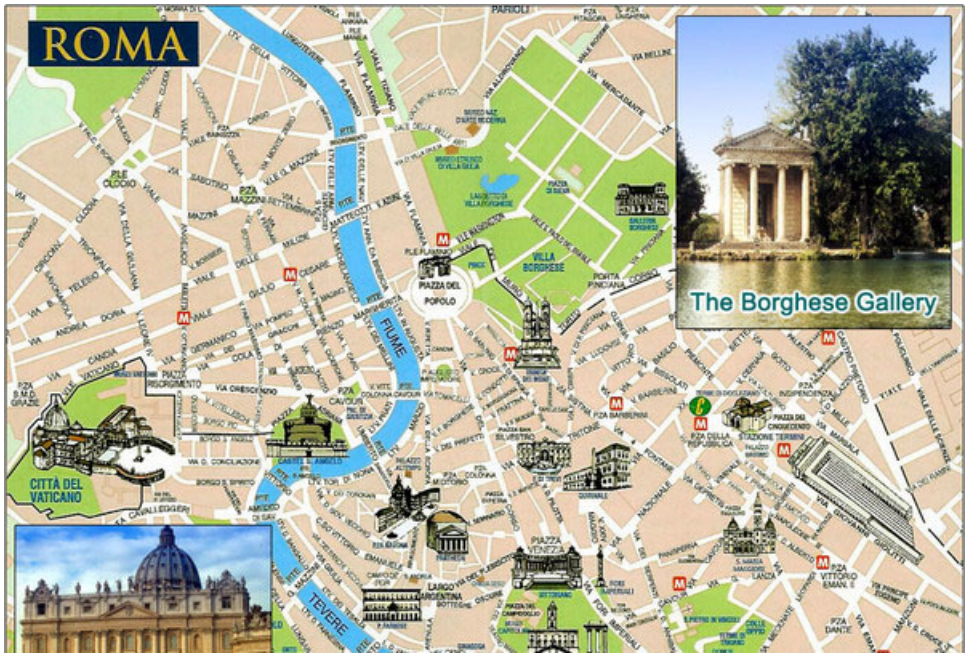

Figure 8. Tourist maps (Oldtown): A walking map showing shopping areas, restaurants, parking in the downtown area, museums, etc.

Figure 9. Topographical maps: A simple "topo" map showing contour lines of terrain relief, major natural features, like rivers and streams, and primary paths and roads.

Figure 10. Utility maps: Show where the power grid, water network, oil and gas pipelines reside in Dystopia. Detail is on the utility sector with minimal other information just for orientation purposes.

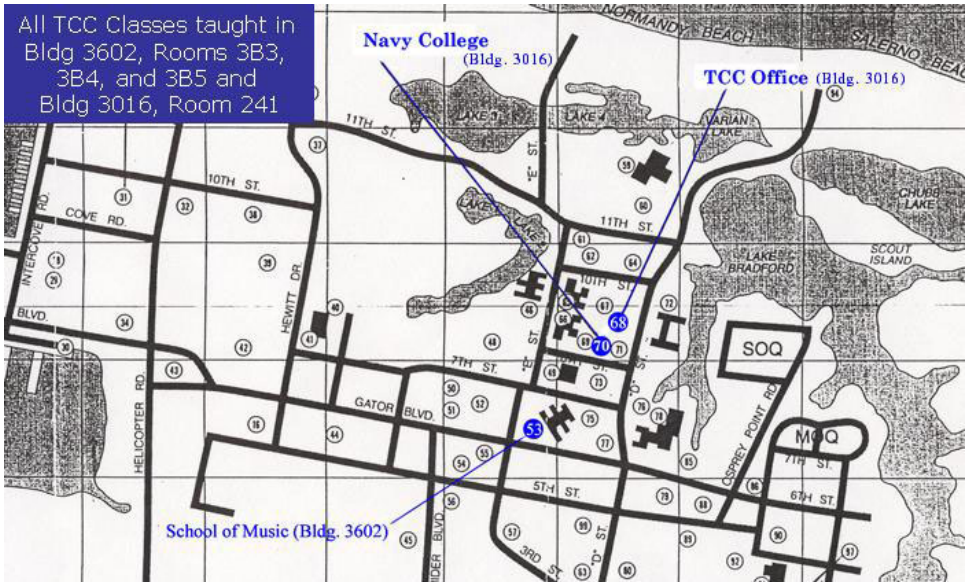

Figure 11. Military base maps: Maps of military installations, similar to the university map with detailed buildings, visitor's center, etc.

Three-dimensional mapping products:

- Terrain skin: The mini-continent that is Dystopia is not a flat piece of land. It has contours, mountains, valleys, rivers, etc. These are modeled in a renderable format for use in 3D Dystopia.
- Detailed models of key buildings and features: For key buildings ("key" being defined as anything any user of Dystopia thinks is important) these are modeled in detail with textures and additional polygons to show the unique shape of the building.
- "Noise" models for everything else: For all buildings that are not deemed "key", there will always be a default building (if we assume that any building sits on that location) that is nothings more than an extruded polygon of the correct height.
- Detailed models of non-building elements (vehicles, signage, lampposts, etc.): Other objects that make up 3D Dystopia that are not buildings have to be modeled for placement in the environment. These include statues, fountains, stop lights, signage, etc.

Metadata (Dystopedia):

- Dystopedia is a wiki-like framework that contains all metadata for Dystopia. It is similar to Wikipedia in design, look and feel, but it is different in that it is not a simple wiki framework. As described earlier, Dystopedia is layered just as the mapping products are layered. The master user can create empty layers for end users to build new meta data to support an exercise or game. That data overrides the existing data wherever conflicts appear. End users then use the supplied web-based editing tools to modify or add new content for their scenario. The player then views the end result which is a composite of the base layer of Dystopedia and any added content from the end user.

2.6 Usage Concept

Dystopia is designed around the use by trusted developers, developers, users.

1. Trusted Developers: Changes to the base layer and core layers in the trusted repository of Dystopia are approved (or created) by the trusted developers. Developers and users are not able to create their own layers on the trusted repository. They can create

anything they wish but only on their own version or layers they create on top of the core Dystopia repository. The trusted developers have access to editing tools that allow for changes to any layer of the Dystopia database, both the geospecific and meta data components.

2. Developers: The developers have access to the same editing tools that trusted developers have but they are only for use on private layers and do not affect the core Dystopia trusted repository. Developers are able to rename objects, create characters and back story, or add historical events that support their exercise or analysis. They can override any element of the core layers in Dystopia but these only affect their local view of Dystopia.
3. Users: Users have no inherent editing ability in Dystopia. Editing for users is likely to be a part of games and exercises that use Dystopia, but within the Dystopia product, users view (browse) and search. They can browse and print the mapping products. They can browse the Dystopedia database. They can perform searches on either search-able maps (not all maps are search-able) or on Dystopedia.

3 Initial Implementation

The initial implementation of Dystopia contains two large urban populations. Cape Hazard is a major port and has a population of more than 287,000. Grim City is a smaller urban environment with approximately 32,000 people residing there. The two cities are separated by a regional boundary that can serve a county line, state line or national border, depending on the requirements of the scenario or analysis. The environment has a major international airport as well as two separate Defense facilities—a fully functional army base located in Grim City and a National Guard training base located in Cape Hazard. Dystopia has a fictional infrastructure that includes power, water, transportation, telcom and oil/gas assets to enable educational scenarios that address Critical Infrastructure issues and challenges. The port facility is built to cover 200 miles of open water to support maritime security and interdiction exercises. Figure 12 provides a high-level illustration.

The sections below describe the status of Dystopia in terms of its technical components and the content that has been built to date. This will include physical descriptions as well as demographics and historical background that has been created to give depth to Dystopia which we have found to be useful for any type of exercise, game, or analysis.

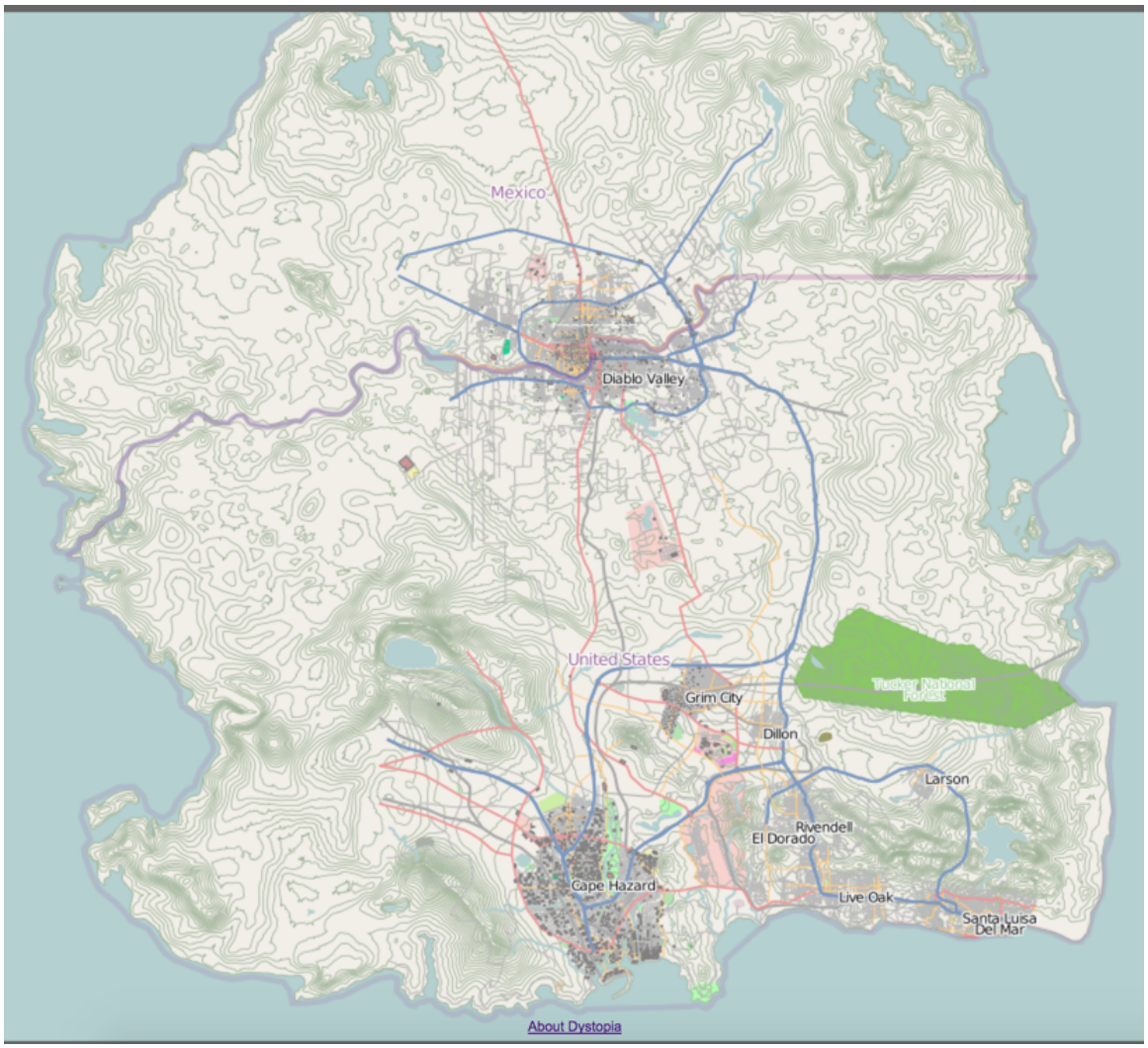

Figure 12. Map view showing the entire continent that is Dystopia.

3.1 Overview

Dystopia contains three distinct project pieces.

1. Dystopia "Physical/Location Data": This data is defined as the fictional geo-typical persistent fictional Dystopia world. It is geo located in a real world space and includes the following features:
    - Spatial GIS info contains 'basic' metadata for rendering, searching and referencing. Table information will also contain web links to additional media and metadata to bind them together.

Figure 13. A map view showing the Dystopedia entry for Grim City.

- Terrain model
- 3D building models

2. Dystopia Metadata/Media: This data provides the contextual information about the environment. It is data that is decoupled from the "Physical Data" and is independently scalable. Information here may be global or scenario specific – as an open source product any researchers or educators using the Dystopia environment are encouraged to contribute to this collection of data.
    - Webpages
    - Dystopedia entries (see Figure 13)
    - Scenario information (media and metadata) to include people, agencies, back stories, and metadata relevant to locations
    - Scenario information (GeoSpatial)
3. Dystopia Rendering/Interfacing Products (RIPs): This data includes the mapping products (2D and 3D) that can used in support on an exercise or analysis.
    - 2d RIPs: static single image maps based upon themes (tourist, university, transit, topographic) pan/zoomable slippy maps (web-based)
    - 3d RIPs: OpenSceneGraph 3d rendering of the world for viewing in open source applications, or compatible with the Unity game engine or similar game engines.

Population 287,000	Percent by race
White	53
Black	15
Hispanic	18
Asian	12
Other	2

Table 1. Population demographics of Cape Hazard.

- Media RIPs: This is the public view or interface into the web media and Dystopedia data mentioned in the Metadata and Media Project piece above.
- Mashups of multiple RIPs: This includes games and simulations designed around the environment, using components from the Physical/Location data and Metadata.

3.2 Demographics and Descriptions

Dystopia is a territory in the US that includes Cape Hazard, Grim City, and the surrounding areas (Figure 14). With its extremely diverse population of over 400,000 people, Dystopia is an exciting, interesting, and always volatile place.

3.2.1 Cape Hazard

Cape Hazard is a coastal port city located in Dystopia. Founded around the Port in 1803, the city has seen steady growth since then due to its relative seclusion and flourishing shipping industry. It is the county seat of Cape Hazard County and is the economic center of the metropolitan area. It is home to miles of beaches, a mild maritime climate, and hundreds of acres of federally protected natural habitat for indigenous wildlife. It is also home to Farber University (Farber U) and the affiliated Farber Medical Center. Farber U is renowned for its agricultural and bioengineering programs, making it one of the leading biotechnology centers in the country. Cape Hazard's economy is largely based on imports/exports, shipping, agriculture, bioengineering and biotechnologies, computer sciences, software development, ship construction and repair, information technologies, telecommunications, and tourism.

The local government of Cape Hazard has a Mayor, a City Council with six members, and a School Board with six members. Cape Hazard is notorious for having not done a lot with

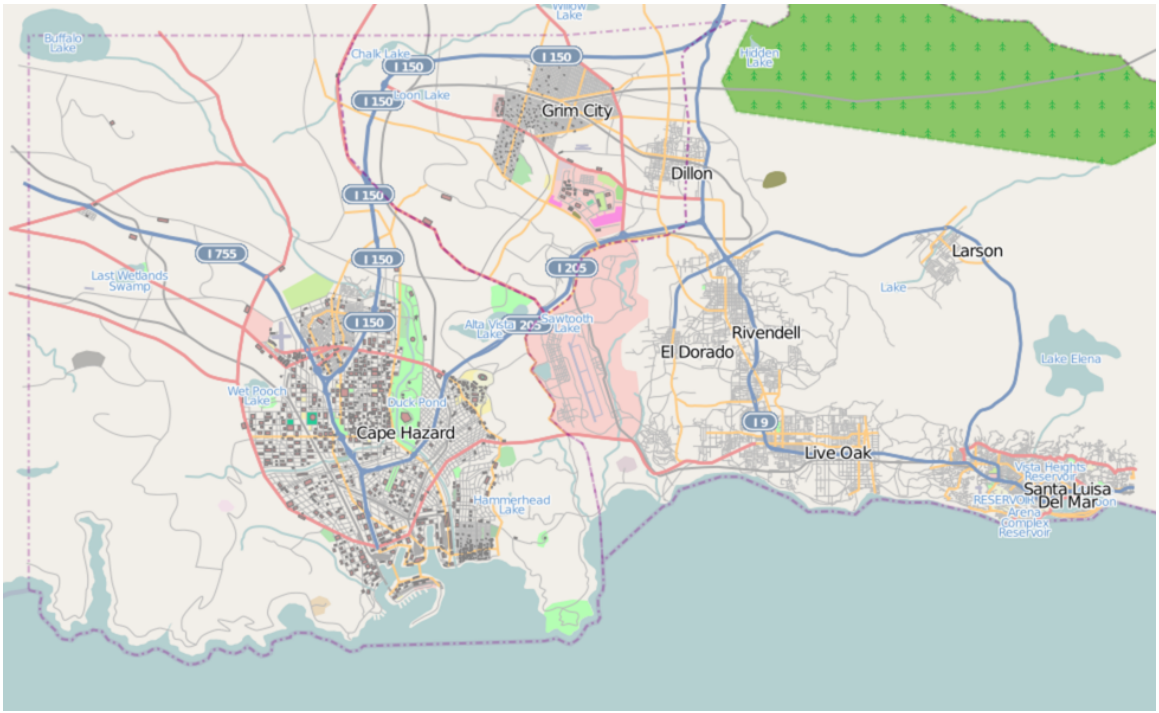

Figure 14. Map view zoomed to show Cape Hazard and Grim City.

regard to homeland security. The Mayor ordered the police force to stop cooperating with the Joint Terrorism Task Force (TF) because she was not given access to all the information provided by the TF that the Cape Hazard police representative received. This problem was resolved but relations between the city and federal agencies are still sensitive.

The Cape Hazard police have developed some access to the environmental movement in Cape Hazard through investigation of previous unlawful activities but have found no evidence of any planning of criminal activity or connections to ELF or ALF, although such connections are assumed to exist. Apart from arresting various skinheads for assault and creating a disturbance, the police have not paid much attention to this group. The city does not have a history of any ethnic or racial problems, although its demographics have been changing as its economy changes.

3.2.2 Farber University

Farber University (Farber U) is a public research university located in Cape Hazard, Dystopia. Established in 1900, it is the only general-purpose accredited college cam-

pus in Dystopia. It has a larger number of locally-originated students than any other university in the nation. Farber U is comprised of the College of Letters and Sciences (the primary undergraduate college), as well as the University Medical Center, the Angelo Roberti School of Engineering and Applied Sciences, and the Henry Maddox Law School. The School of Engineering has its own research nuclear power facility that resides on the campus. It is best known for its agricultural and bioengineering programs, making it one of the leading biotechnology centers in the country. Because of its extensive research in the bioengineering field (including research on genetically modified foods), Farber U has more recently become a hotbed of anti-GE activism and the center of some very public and heated debate.

3.2.3 Port of Cape Hazard

Cape Hazard is among the top ten container ports in the US, with products valued at 23 billion dollars crossing its docks each year. It is served by 29 ocean carriers, transcontinental railroads, and numerous trucking companies that link Cape Hazard to market hubs throughout North America. The Port encompasses nearly 500 acres of container handling space, with 19 container cranes and facilities.

3.2.4 Stockton International Airport

Stockton International Airport (SIA) is a city-owned, public-use airport located at the Northeastern end of Cape Hazard, about 4 km from the downtown area. It can be accessed via car off of Highway 452 or via lightrail service from downtown Cape Hazard. SIA is considered one of the major international gateways connecting Asia and Europe with the US. Each week there are over 45 scheduled flights to international destinations. SIA is home to 28 different airlines, 9 of which are foreign flagged and 5 of which are all-cargo. Over the course of 2006, passenger traffic exceeded pre-9/11 levels, climbing 7.5 percent. In 2007 28.8 million passengers passed through the airport, along with 346,966 metric tons of air freight.

3.2.5 Critical Infrastructure

In its initial implementation, Dystopia contains an international airport, a sea port, a nuclear power plant and associated power grid (Figure 15), telecommunications system, freight rail,

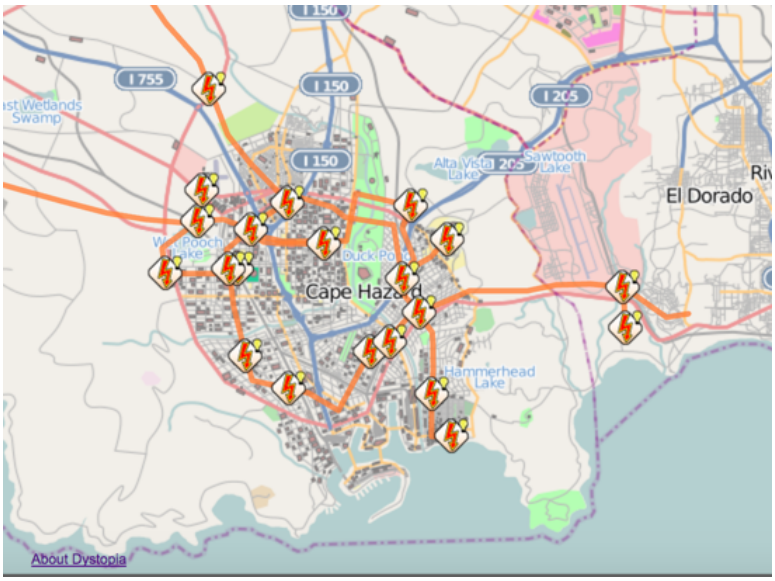

Figure 15. Map view showing the power grid in Cape Hazard.

Population 31,720	Percent by race
White	73
Black	10
Hispanic	14
Asian	3
Other	.5

Table 2. Population demographics of Grim City.

passenger rail, and municipal utilities that include water, waste water treatment, power, production facilities, and natural gas.

3.2.6 Grim City

Grim City is a city located in Dystopia, adjacent to the nearby Cape Hazard. While it is smaller than Cape Hazard both in population size (Table 2) and area, Grim City remains an important part of the Dystopian economy.

3.3 History of Cape Hazard

The island of Dystopia, according to geologists, was originally connected to the North American mainland, but then separated through the long, slow process of Continental Drift. Thus, while sharing much in common with the mainland, Dystopia exhibits species of flora

and fauna uniquely its own. The original human inhabitants of Dystopia were the Pwakito Indians. Indian artifacts, as old as 35,000 years, have been discovered on the island. The Pwakito were an agrarian people, sophisticated in the cultivation of parsley, sage, rosemary, and turnips.

In the middle 18th Century, American traders established relations with the Pwakito. An early Caucasian settlement began to grow at the mouth of Indian River, in the area now known as Oldtown. With the success of the settlement, docks to accommodate larger vessels were built on the west side of the river. During harvest time, there were often more ships than berthings, forcing the extra ships to anchor in Commerce Bay awaiting a vacancy. The Commerce Bay Shipping Association was established in 1799 to manage the congestion.

In 1802, a hurricane of unexpected intensity impacted the southern Dystopia seaboard causing many anchored ships to crash into each other and sink. Seamen began calling the area Cape Hazard, and this name caught on for the town that formed along the west side of Indian River. Even today, treasure-hunters dive into the treacherous waters of The Ocean searching for the chests of gold coins that are alleged to lay buried within the sunken hulls. A second settlement, originally known as the Hayfield Trading Post, was established inland by white farmers in 1805. Eventually, it became the township of Hayfield.

On June 2, 1841, a group of farmhands, spurred on by rumors of cannibalism, journeyed at night to the Pwakito village at the base of Anthill Mountain, and burned the teepees with torches. The Pwakito huddled in their ceremonial cabin for safety, however several Indians, some of them children, were killed in the melee. The cannibalism rumors proved to be unfounded, but the damage had been done. On June 17, 1841, the young warriors of three Pwakito tribes converged on Hayfield at sunrise. By the time the screaming had subsided, seventeen Indians and twenty-four settlers lay dead in the streets of Hayfield. This event came to be known as the Grim City Massacre, and in time Hayfield became known as Grim City, the name it bears today. In response to the complaints of the settlers, the U.S. Bureau of Indian Affairs signed a treaty with the Pwakito elders that resulted in the Pwakito being relocated to a remote part of New Mexico. When the Pwakito heritage is celebrated today, modern-day Pwakitos are hired as actors to portray their ancestors.

On March 20, 1853, oil was discovered beneath the high plains of northwest Dystopia. The main challenge was in transporting the black gold out of Dystopia since the rocky bluffs of

the northern seashore were completely ill-suited for ocean access. In response, Justis Farber, a former sea captain and shipping magnate, broke ground on a railway line connecting the Cape Hazard dockyards with the new oil fields. This event is commemorated in an epic 14×8-foot oil painting which now hangs proudly in the lobby of the Farber University Administration Building, the university established by Justis Farber in 1868. The colorful painting depicts the heroic Farber, pickaxe swinging over his head, preparing to carve the first scar in the sod, as many distinguished members of the community look on with admiration.

The initial rail line was completed in under two years. The resulting economic boom gave rise to the city of Cape Hazard. The area surrounding the docks had already grown into a center of shipping and fishing. In parallel, the banking and financial center that serviced the industries took root several miles inland. It was traditionally believed that the detached location emerged because the era of high-rise office buildings required a firmer bedrock foundation than could be found nearer the shore; however, the recent book by historian C. Davis Sebastian, A Blight Unto Thy Senses (Farber University Press, 2005), has established that the businessmen were driven away by the overpowering smell of the canneries.

When the War Between the States erupted in 1861, Dystopia Governor-General Alonzo Proboscin Wickersham declared the island to be officially neutral in the conflict. His proclamation, signed and stamped with the Seal of Dystopia, was sent by steamship to Washington with a shipment of sunflower seeds. But the ship went badly off course and is believed to have sunk off Cape Horn, depositing the inflammatory document into Davy Jones' locker. Neither the Union nor the Confederacy ever called the people of Dystopia to account; likewise, the people of Dystopia never complained about being forgotten, and thus were unexpectedly exempted from what turned out to be a rather nasty little conflict.

With prosperity also came problems. Beginning in the 1890s, when Cape Hazard experienced its most rapid growth, labor was imported from Eastern Europe and Asia, primarily workers for the canneries and oil fields. From 1895-99, many workers were brought in for the sole purpose of dredging the Commerce Bay channels and constructing Tadpole Island from the refuse. Many men, making subsistence wages, and their families, lived in cramped shanty quarters in lower Westside and Tadpole Point, as well as in Oldtown tenement flats. In early-1900, while most of the United States celebrated a new century

of unlimited promise, typhus ripped through Cape Hazard, killing over 4,000 people, and leading to the creation of the Department of Sanitation.

In the early years of the 20th Century, even more workers were brought in, both from abroad and from other parts of the U.S., to construct roads for the latest triumph of the Industrial Age, the automobile. Within a very few years, the present layout of the city had been "written in asphalt." During this period, Cape Hazard became a patchwork of ethnically-segregated fiefdoms, which outsiders entered at risk. Gang wars, turf battles, and race riots became the stuff of legend. Over the course of a century, these neighborhoods changed complexion as upwardly-mobile workers migrated to outlying areas and, after WWII, the sprouting suburbs. As one group melted away, a new economically-challenged group would flood into the old neighborhood and remake it in line with their own special tastes and customs. Thus did areas like Little Egypt and the Polish Quarter disappear, consigned to historical footnotes. Today, the public tends to remember the most vivid aspects of Dystopia's immigrant past—the crushing poverty, the glorified violence, the struggle to achieve Democracy's promise of equality—but we may also see in our history the seeds of Dystopia's rich diversity being planted.

Dystopia's pacifist tradition was put to the test, and found wanting, when the U.S. entered the Great War in 1917. An Army training facility was hastily constructed on open land southwest of Grim City. Originally, it was propagandistically named Camp Hunstopper; now it is the Fort Pershing Army Base. Over 16,000 young men from all over Dystopia passed through Camp Hunstopper on their way to France. Three thousand of them never returned; a memorial to their sacrifice is located in Westside, near the intersection of Longsock Road and Yumpcray Street. Camp Hunstopper was also the site of a training facility for battlefield nurses; it's now called the Fort Pershing Military Hospital and still trains many nurses for military service.

The WWI veterans, known to Dystopians as The Feistiest Generation, were a battle-hardened group of young men who couldn't be told what to do. Thus, when Prohibition became the law of the land, the feisty fellows and felons turned the dockyards and the back alleys of Oldtown into a national capital of bootlegging and illicit saloons. This led to the birth of the tourism industry, as visitors from around the country flocked to Dystopia for "drinking holidays." Hotels, restaurants, and amusements of all kind sprang up to accommodate the

tourists, earning Cape Hazard the nickname "North Havana." The money generated on the black market was immense, and local officials were corrupted by bribes to ignore the problem. As an old gag went, ask a stranger in Oldtown, "Where can a guy get a real drink around here?" and the answer was: "Anywhere but the Post Office." A local recipe, the Sea Monster, which mixed rum, pink lemonade, and other random ingredients, became the cocktail of choice.

Rival gangs competed to control distribution of the imported booze. The murder rate skyrocketed as a result of friction between the gangs, who failed in repeated attempts to organize into a unified coalition. Street shootouts, which claimed many innocent victims, were commonplace. The most famous confrontation, The Battle of Trigger Street, pitted dozens of Tommy-gun-wielding hoodlums in a merciless fight to the finish. When the smoke cleared, Trigger Street was revealed to be a virtual wrecking yard of crashed automobiles, geysering fire hydrants, broken glass, bullet-riddled bodies, and ownerless fedoras. Alarmed by the rise in lawlessness, in 1931 Mayor Johnny O'Malley appealed to the U.S. Attorney General for help. A massive influx of government agents was brought to bear on the gangs. For his efforts, Mayor O'Malley was gunned down by two assassins as he stepped outside of his favorite restaurant, Copperfield's Steakhouse. The gunmen, believed to be associates of mob boss, Al "Nosey" Parker, were later found hanging under the Main Street Bay Bridge.

Prohibition was appealed in a little over two years later, but the era left an enduring legacy. The Federal Government presence in downtown Cape Hazard, which greatly expanded during this time, remained and even continued to grow. The saloon scene, made legitimate overnight, remained a tourist hotspot; now, the proliferation of bars around Oldtown's Main Street is a vibrant center of activity, particularly during the summer months and Spring Break.

Fort Pershing, which diminished in importance between the wars, returned to prominence as men and women were mobilized for action after the December 7, 1941 Japanese attack on Pearl Harbor. Over 35,000 soldiers received basic training at the facility; when weekend passes were issued, the streets of Oldtown were mobbed with soldiers hoisting Sea Monsters. The old Empire Ballroom, featuring live bands nightly, became the social center of the city. (The Empire went out of business in 1953, with the end of the Korean War. The cavernous building, on Calamity Jane Street, between Redwood and 4th Avenue, now houses the

Goodwill Industries.) After WWII, many soldiers returned to Cape Hazard to settle; a great number earned degrees at Farber University using their G.I. Bill education benefits. Many others used the Bill's low-interest loan provision to buy houses. The suburbs, especially in Westside, Eastbank, and Grim City north of the railroad tracks, grew rapidly in this period.

At the cessation of the Korean War, Fort Pershing went into another of its periodic hibernations. There had been a traditional boom-or-bust relationship between the activity of the fort and the local economy, but after twelve continuous years as an important military facility, the downsizing of the fort led to a severe recession. At first, only the robustness of the energy sector, specifically the oil industry and the emergence of Cape Hazard as a center of nuclear research, offset the downturn.

In 1955, Mayor Robert G. Hendershott's Bright Future Initiative spelled out the plan for the city's development. A major provision of the BFI was the upgrading of public transportation; this resulted in 1) the expansion of Stockton Airfield into a major international hub, 2) the construction of DLight, the Dystopia Lightrail System, 3) support of Federal efforts to construct Interstate highway links on the island, and 4) the reengineering of the harbor to accommodate cruise ships. A complementary provision was to develop Cape Hazard into a center for international business and tourism. Tax codes were rewritten to induce domestic and foreign entities to open facilities in downtown Cape Hazard. The development of international tourism took a multi-pronged approach: 1) the Oldtown Renovation Project resulted in road upgrades and improvements to city services; provided subsidies to local businesses to renovate historical buildings in accordance with a revamped Building Code; and supplied the funding for the construction of The Aquarium and the Nautical Museum; 2) Indian River Park was developed with tourism-friendly facilities, including the Riverboat Rides, the Botanical Gardens, the Monkey Houses, the Merry-Go-Round, and other features; 3) The construction of the world-class Wasted Youth Indoor Sports Arena (since rebuilt and expanded).

It all sounded wonderful on paper, but the requisite raises in local tax rates made the plan controversial, and guaranteed that the BFI would take longer in coming to fruition than Mayor Hendershott had originally set forth. There were so many construction projects underway simultaneously that citizens complained that the traffic delays and inconveniences had made Cape Hazard life unendurable. The Mayor barely survived a reelection challenge

in 1958. When Hurricane Marciano struck Cape Hazard in 1959, destroying a year's worth of work on the harbor reconstruction,The Cape Hazard Courier ran an infamous headline reading "Marciano 1, Hendershott 0." Though the paper later apologized in an editorial, damage more severe than the storm's had been done: a widespread perception lingered that the BFI had been a boondoggle. But Mayor Hendershott persisted in defiance of his critics. By 1962, many of the improvements had reached completion. The city had, in fact, become an international destination, vindicating the mayor's vision. At the inaugural Cape Hazard Film Festival (February 1963), held at the Orson Welles Public Theater, Italian director Federico Fellini and actress Anita Ekberg appeared in conjunction with a special presentation of La Dolce Vita. The next year, the Beatles played the Wasted Youth Indoor Sports Arena. Halfway through their 24-minute set, they laid down their instruments long enough to dedicate their following song, "Money (That's What I Want)," to "a good bloke, Mayor Hendershott." Apparently quite moved, the mayor ran from backstage, took the microphone, and announced his retirement with the end of the current term.

In 1965, Fort Pershing ramped up yet again, this time to train draftees for the Vietnam conflict. Growing resentment among the youth of Dystopia led to Farber University becoming a hotbed of antiwar sentiment. Caravans of buses painted in flower-power motifs were constantly driving up I-205 to Fort Pershing to stage sit-ins at the base gates. At times, the ostensibly peaceful protests got out of hand, leading to all-night battles between hippies and Dystopia National Guardsmen. After four Guardsmen were shot and killed at five a.m. on the morning of June 4, 1968, President Nixon declared that "Violence is anathema to a modern democracy," and called for peace talks. A year-and-a-half of contentious negotiations ensued, leading to all parties signing the so-called Midnight Agreement on December 31, 1969, affirming in principle that the '60s were over.

Also at an end were the years of construction and rebirth for Dystopia. What followed was peace, quiet, and relative affluence, a city in "satisfaction mode," as Farber University Sociology Professor Dave Edwards put it. Mayor Christian Santee (successor to R.G. Hendershott) and the City Council responded by lowering property taxes to pre-BFI rates. Suburban houses got bigger, often with two stories instead of one; garages expanded to handle three cars instead of one. Average family size steadily rose from 2.3 children per household to 3.4. With the proximity to cheap, refined gas, private vehicles got bigger, too. Income from tourism began to dip. By 1979, Oldtown was better known for prostitution

and drug overdoses than it was for wholesome entertainment. Mayor J.D. Jennison formed a fact-finding committee to study the situation and recommend changes. The committee was eventually disbanded as a result of budget cuts and never issued a report.

In the ’80s and ’90s, while the rest of the country enjoyed relative peace and prosperity, Dystopia suffered a seemingly unending series of civic crises:

- On Easter Sunday of 1983, locusts swarmed from the northeastern hills destroying agriculture in Green Valley and terrifying the residents of Grim City. In 1984, and thenceforward, the event has been commemorated in Grim City with the weeklong Easter Swarm Festival, climaxed by the crowning of Miss Locust.
- In 1988, skin-headed Spring Breakers and police clashed on the Oldtown beaches off and on for three days. Tear gas was used to break up the mobs. The Courier ran a now-famous photo of a surfer just offshore on his board holding a sign that said, “Come and get me.” Excessive consumption of alcohol was identified as the primary cause of the disruptions. As a response, laws relating to alcohol sales, outdoor drinking, and public drunkenness were modified.
- In 1990, vacationing Scandinavian bikers on rented Harleys turned Grim City into a scene of post-apocalyptic mayhem.
- Later in 1990, a private airplane took off from Grim City Airport, ascended to 300-feet of elevation, then nosedived into the Auto Mall, totaling five new Mazda RX-7’s and killing the pilot. A heart attack was determined to be the cause of the pilot error.
- Five Palestinian gunmen wearing ski masks attempted to invade the Israeli Consulate. Two consular guards were shot and killed, as were four of the gunmen. The fifth committed suicide after being cornered by police in Traffic Music Park. The incident made international news in 1993.
- In the record-setting heat waves of the summer of ’96, the Dystopia power grid underwent several major blackouts. This was blamed on outdated and inadequate equipment. When KLGL-Channel 25 reported that the resulting deaths of senior citizens fell disproportionately on members of minority groups, widespread looting spread through the dark streets of Westside. A number of local businesses were burned to the ground.
- An influx of undiluted Taliban-grade heroin into the Dystopia drug underworld resulted in a disheartening number of overdose deaths and hospitalization cases over

1997-99. Drive-by gang shootings, sometimes victimizing civilians, rose to record levels.

In 1998, Mayor Jennison declared Dystopia the "disaster capital of the world, maybe even the galaxy." He initiated an essay contest and encouraged all of Dystopia's students to submit entries on the topic: "What's Wrong With Dystopia?" Prizes of 100, 50, and 25 dollars were awarded. Winning entries were posted on the city's website. But nothing changed. One disaster after another, each one uniquely different from its predecessors, visited the once-proud metropolis. Fire Commissioner Lance Atkinson complained to a film crew recording a particularly horrendous scene of devastation, "What good is it studying the past, if the future won't play along?" He made the six o'clock news and later apologized for the remark.

In 2005, a Cape Hazard Courier phone poll attempted to measure the quality of life in the twin-cities area. When they were asked to best describe their feelings toward Dystopia, citizens responded thusly:

13 percent	I think things are going just about right
10 percent	I have a defiant almost militant optimism
21 percent	Life is struggle
34 percent	I would move away if I could afford it
13 percent	I'm in a state of perpetual fear
9 percent	No answer

As the coming season approaches, the residents of Dystopia can only hope that terror, calamity, disaster, destruction, fear, and the other tin soldiers in Satan's toy box take a much-needed holiday.

3.4 Character Biographies

Atkinson, Lance [b. 1961]: Fire Commissioner, 2003-07.

Daniels, Hendrik [b. 1952]: Fire Commissioner, 1990-2003, after which he joined the Department of Homeland Security.

Doyle, Brenda [b. 1949]: Chief of Police, City of Cape Hazard, 1995-present. Native of Philadelphia, Pennsylvania. Enlisted in the U.S. Army after finishing high school in 1967. Served for six years, including four years of active duty in Vietnam. Graduated from Lehigh University, Pennsylvania, with a B.A. in Education (1977). Received a Master's of Criminal Justice from Farber University (1980). Worked as a Detective Investigator for the Jacksonville, Florida, Police Department (1980-86); and served as Assistant Chief in the same department (1986-95). Chief Doyle has distinguished herself during her tenure by: 1) strengthening the department's continuing education program, and 2) overhauling the department's procedures in the areas of crime scene investigation and witness interrogation, bringing the department into compliance with the most rigorous Department of Justice guidelines. After the retirement of Cape Hazard Police Chief Don Wilcox in 1995, a nationwide talent search was initiated for his replacement, which finally resulted in the hiring of Chief Doyle to take the position. Under Chief Doyle's leadership, the police Department has made a major shift toward community policing, which has resulted in lower crime rates and a higher quality-of-life in all districts of the city.

Hendershott, Robert Gladwell [1901-79]: Mayor of Cape Hazard, 1954-1962. Spearheaded the creation of the DLight, the Dystopia Lightrail System.

Rodriguez, Sidney [b. 1953]: Mayor of Cape Hazard, 2002-present. Mayor Rodriguez was born in Phoenix, Arizona. He spent his teenage years living on the Army Base while his father served as Gunnery Sergeant in the U.S. Army. He graduated from Grim City High School in 1971. He received a B.A. in Political Science from Farber University (1975); and a Master's in Public Policy from Princeton (1977). Upon graduation, he worked in Pest Control Administration for the U.S. Department of Agriculture in Cape Hazard. In 1987, he left the D of A to co-found Rodriguez & Bell, a consulting firm. In 1990, he unsuccessfully ran for Cape Hazard City Council. In 1994, he was elected to the City Council with 56 percent of the vote in his district of Eastbank. In 2002, he was elected to the office of Mayor of Cape Hazard in his first attempt. As Mayor Rodriguez said in his 2002 Inaugural Address: "There is no conflict between government, industry, or our other great institutions, that we cannot resolve. We will continue to make this a great city to live in for every citizen."

Townsend, Charles "Buck" [b. 1968]: Fire Commissioner, 2007-present. "Buck" Townsend is a 23-year veteran of the Cape Hazard Fire Department. After graduating from Cape Hazard's St. Bonaventure High School in 1986, he joined the department as a summer intern to assist during the annual wildfire season. His unflinching dedication soon earned him a regular appointment at the rank of Apprentice Fireman. He was promoted ahead of schedule to Fireman, and then Crew Chief. In 1994, he received a B.A. in Public Administration from Farber University Night School. Degree in hand, he served as an executive in all major Fire Department divisions and was appointed to Deputy Fire Commissioner in 2000, serving under Commissioner Hendrik Daniels. When Commissioner Daniels left the department in 2003 to join the U.S. Department of Homeland Security, Deputy Townsend served as second-in-command to newly-appointed Commissioner Lance Atkinson. Upon Commissioner Atkinson's departure in 2007, Deputy Townsend was appointed Fire Commissioner.

Wilcox, Donald James [b. 1930]: Chief of Police, City of Cape Hazard, 1985-95; Chief Burglary Unit Investigator, 1979-85. After retiring in 1995, Chief Wilcox relocated to Fort Myers Beach, Florida to be nearer his grandchildren, and to indulge his passion for deep-sea fishing.

Williams, Munson Steven (Independent) [b. 1963]: Governor of Dystopia, 2004-present. Governor Williams was born and raised in San Leandro, California. He graduated from Moreau Catholic High School in 1981. He attended Ohlone Junior College in Fremont, California, achieving an Associate Degree in Computer Studies (1983). He transferred to Farber University to study Computer Science. After two semesters, he left school to establish the business, PC Repair and Instruction. He sold the business in 1989, after it had expanded to 11 sites, and spent two years touring the United States as bass player for the rock band, Boomboombox. In 1992, he opened his first Java Junkies coffee shop in Cape Hazard. By 2001, Java Junkies had expanded into a 170-location franchise in Dystopia and adjacent states. Mr. Williams sold the business for a reputed 2.7 billion dollars and began his successful campaign for Governor. Known for his wit, he was famously quoted in a Grim City Daily-Democrat interview (March 19, 2006) as saying: "As soon as I climb Mt. Everest and start my own airline, I won't need Richard Branson as a hero anymore. I'll just look in the mirror."

4 Modeling Critical Infrastructure Systems

The geospatial, demographic, and character data in Dystopia provides a rich context for discussion, role play, and tabletop activities, but on their own they are insufficient for addressing the research and education problems being faced by modern critical infrastructure systems. Although the initial implementation of Dystopia provides a number of data layers representing critical infrastructure systems (e.g., Figure 15) that can be turned on or off for display purposes, these layers are little more than artwork. From an engineering perspective these layers are completely unrealistic; i.e., they do not reflect the physics and operating reality of critical infrastructures and would not function if built. Nor could they be used to understand how these systems will perform in the presence of a disruptive event (e.g., a natural disaster). As one researcher put it, they are little more than "crayola on a map".

Instead, there is a need not just for infrastructure data but for *models of infrastructure function*, so that one can understand and explore the behavior of these complex systems in a variety of scenarios. As noted by Alderson (2019), there are three common questions asked about critical infrastructures:

1. What are the consequences (in terms of loss of function, damage, or lives lost) from damage or some disruption scenario?
2. What are the most important (i.e., most *critical* components of the system?
3. How should limited resources be invested to mitigate the vulnerability or potential disruption to the system?

The ability to represent infrastructure system function in Dystopia offers the potential for a novel and important platform for studying them.

4.1 Use Cases

Alderson (2019) articulates a variety of reasons why there is a need for a platform like Dystopia for studying "realistic, yet fictitious" infrastructure systems.

1. The study of real infrastructure systems typically reveals vulnerabilities that create strong disincentives for system owners and operators to share detailed information. Working on fictitious system data does not create such disincentives.

2. There are few canonical data sets for the study of critical infrastructure function. Often,

these are domain-specific. For example, the IEEE publishes standard power distribution system data for purposes of testing and evaluation (Schneider et al. 2017). As noted in Hernadez et al. (2016), the ASCE Task Committee on Research Databases for Water Distribution Systems has supported the identification and collection of "data files and supporting narratives for over 40 different [water] distribution systems" (online database at www.uky.edu/WDST; last accessed 28 December 2019). There is also an online repository of road system data (Transportation Networks for Research Core Team 2019). With the exception of a nascent platform under development by the NIST-funded Center for Risk-Based Community Resilience Planning (Center for Risk-Based Community Resilience Planning 2017), there is little in the way of a platform for modeling interdependent infrastructure function. In the current research environment, there are

- no standards for data sets as model inputs,
- no standard functional models,
- no benchmarks for comparing algorithm performance, and
- no canonical examples of resilience or brittleness.

As a result, each study is a one-time result, making it hard to teach and learn about infrastructure resilience.

3. There is a need for case studies that can be shared and used for purposes of teaching. As noted from the outset, the key to this type of learning is detailed context.

Dystopia has the potential to serve as a platform for benchmarking systems and algorithms, studying cascading behaviors, and exploring new ideas for system design. It can be used for training and exercises, as well as education and outreach. However, there are a number of implementation challenges.

4.2 Implementation Challenges

Dystopia has the potential to serve as a platform for modeling and analysis of infrastructure function. The basic idea is to connect the data layers to a simulation engine that supports domain-specific models of infrastructure operation (Figure 16).

The goal of using Dystopia in this way is to assess the capability of the imagined infrastructure systems to operate (e.g., satisfy demand) both during normal operating circumstances

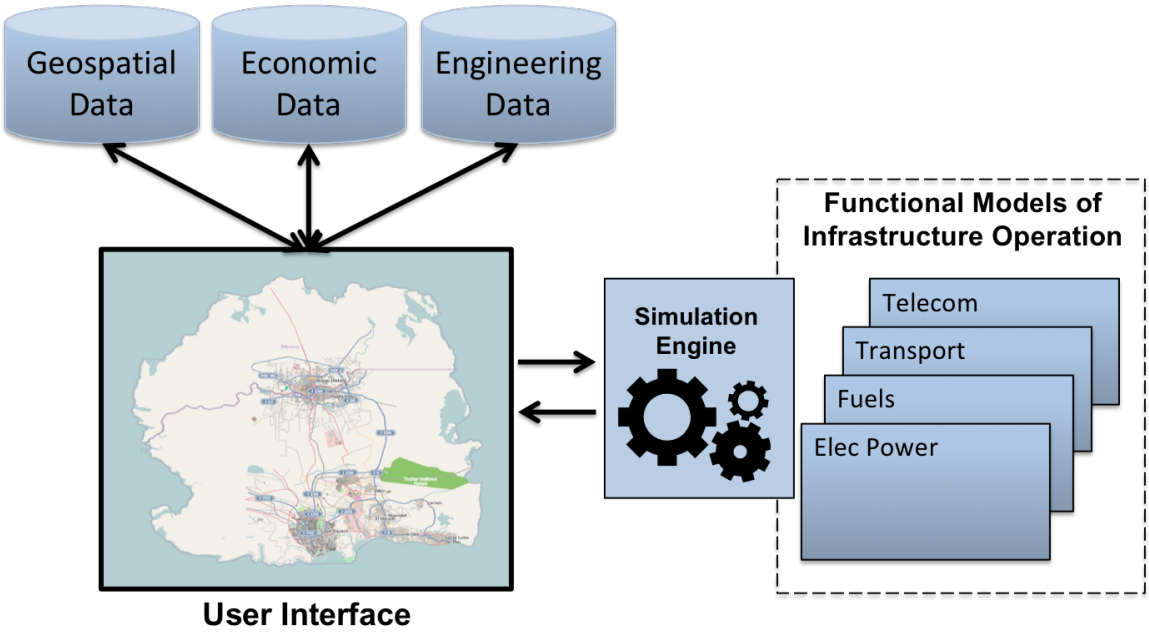

Figure 16. Overview of Dystopia as functional modeling platform as originally conceived in Alderson (2014).

as well as during stressful events. The ability to consider various "what-if" scenarios is fundamental to vulnerability assessment, identification of critical components, and exploration of mitigation strategies.

It is important to note that the use of Dystopia in this way is not intended to be used for real-time situational awareness.

One preliminary attempt to build this type of functionality into Dystopia was conducted by Martin (2014), who modeled a notional fiber-optic communication system. Figure 17 (left) displays a realistic fiber system, including both underground and offshore (underwater) cables. Figure 17 (right) shows the performance of the system under an imagined failure scenario, with colors indicating the performance of individual fiber segments. The colors in this figure represent the *output* of a simulation model (really, a prescriptive decision model) that shows the best possible way to run the system in response to this failure.

To facilitate the transfer of data to and from Dystopia layers, Martin (2014) developed a workflow using eXtensible Markup Language (XML) that interfaced with an optimization-based flow models in the General Algebric Modeling Systems (GAMS); see Figure 18.

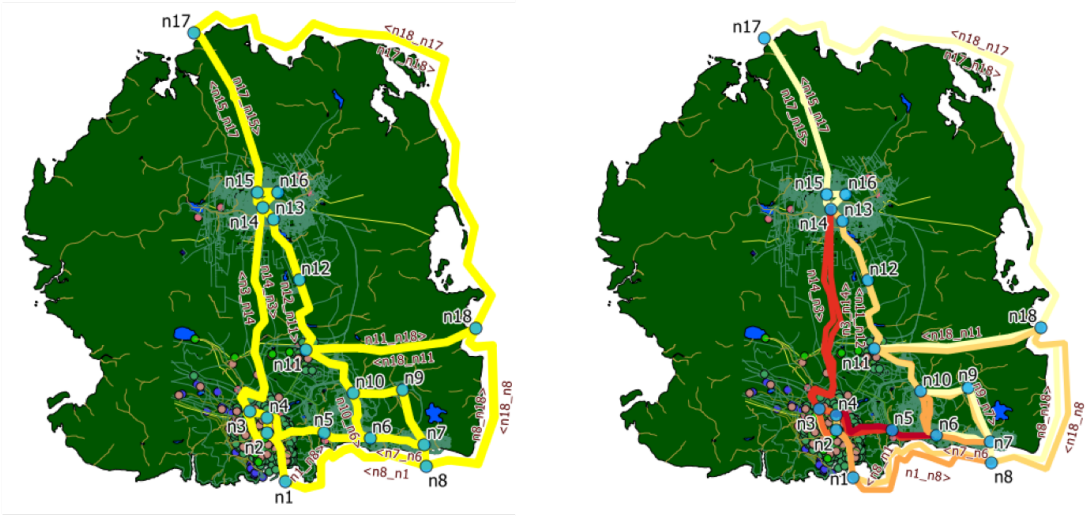

Figure 17. A notional fiber optic network for Dystopia (from Martin 2014). LEFT: a realistic network containing engineering details sufficient to build and deploy in practice. RIGHT: performance of the network during a simulated failure.

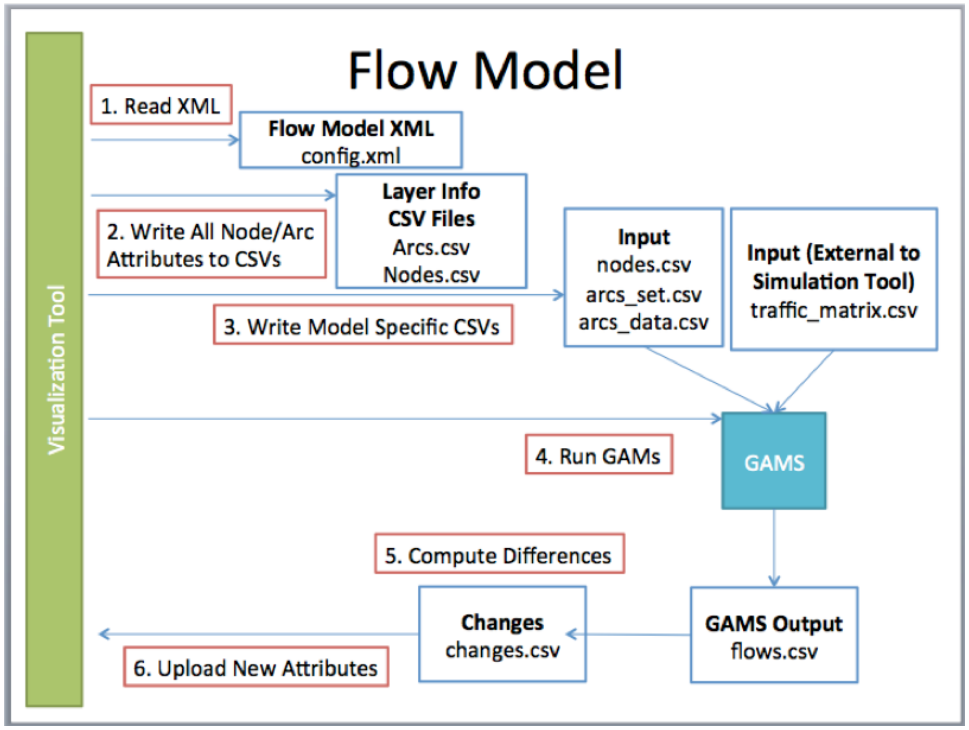

Figure 18. Modeling workflow in Martin (2014).

A challenge in developing models of infrastructure function is the need to curate appropriate domain-specific data to use as model input. In many cases, data used for visualization purposes is insufficient for modeling the operation of the system. For example, the shapefiles used to visualize a road network in a geographic information system (GIS) typically will not contain engineering data—such as road type, road condition, number of lanes, speed limits, etc.—needed to simulate the flow of traffic. This requires considerable effort to develop the data in parallel to constructing the model; see Good (2019) for a recent effort.

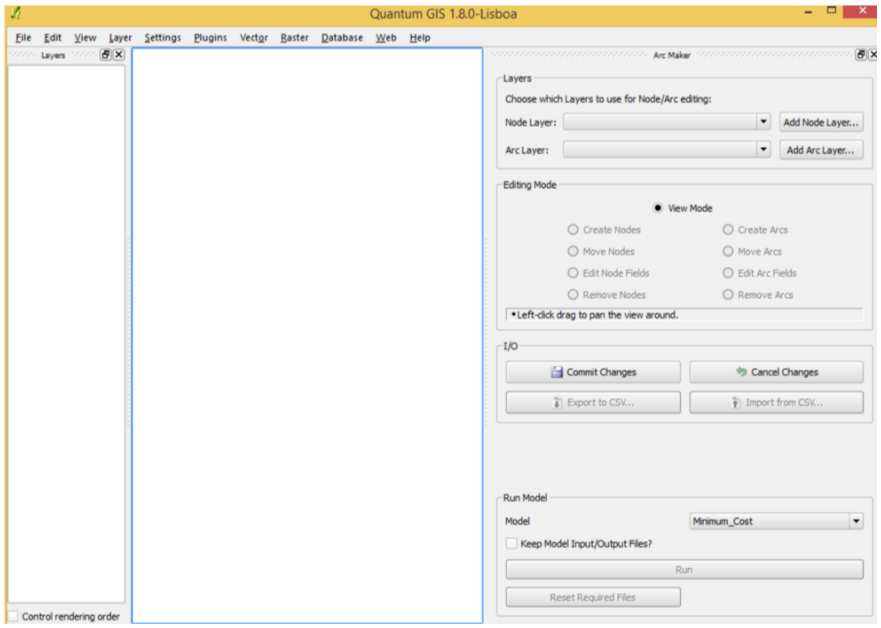

Figure 19. A simple plug-in for QGIS—a free and open-source cross-platform desktop geographic information system—to support development of realistic infrastructure network data.

A preliminary effort in parallel to the work by Martin (2014) led to the development of customized applications intended to support the development and publication of infrastructure data within Dystopia. Figure 19 shows one version of an application (implemented as a plug-in for the QGIS desktop application) to allow a developer to quickly draw an infrastructure network and annotate it with the domain-specific information needed for the corresponding operational model. The intent was to follow the original Dystopia concept of trusted developers, developers, and users, with different levels of permissions for creating core infrastructure data as well as scenario-based data (e.g., representing a natural disaster or terrorist attack).

The ultimate goal is to be able to perform the types of analyses described in Brown et al. (2006); Alderson et al. (2014, 2015), including the use of attacker-defender models to identify worst-case disruptions to infrastructure function, as well as the use of parametric analyses to assess how an infrastructure system will perform under increasing stress. For example, we imagine that a user of Dystopia would be able to exercise these types of analyses or select from a number of predefined threat scenarios. However, the development of customized interfaces to support this interaction remains a topic of discussion.

4.3 Recent Advances

The last several years have brought recent advances in the modeling and analysis of interdependent critical infrastructure systems, as well as improvements in supporting computational infrastructure. Ruether (2015) demonstrates how the use of Pyomo-based optimization models (Hart et al. 2017) can streamline the computational workflow conceived in Martin (2014). Petri (2017) develops a three-phase alternating current electric power distribution model for analysis of regional electric infrastructure systems. Bunn (2018) and Wille (2019) show to combine electric power and water distribution models in simulation-optimization for analysis of interdependent power-water systems. Good (2019) develops a surface road transportation model to support analysis of supply chain resilience.

These and other operational models of interdependent critical infrastructure systems are available for application to Dystopia.

5 Future Opportunities

Dystopia has proven to be a useful tool for classroom education, however, it has the broader potential to serve as a platform for research on critical infrastructure at the level of an installation, metropolitan region, island or territory.

Policies and practices for infrastructure design, operation, and reconstruction have placed increasing emphasis on *resilience*, to strengthen the ability of systems to prepare and recover from catastrophe. Nonetheless, Alderson (2019) details four fundamental barriers to infrastructure resilience symptomatic of a scientific field in which practice has outstripped theory (See below). Unlike other disciplines in the physical sciences and engineering, in which advancements in fundamental science mature into novel technological capacities,

resilience research has struggled to keep pace with demand for reliable measures, models, or experimental results that empower practitioners.

Ultimately, we need to understand the collective and interdependent operation of three types of systems

- technological systems (a.k.a. built infrastructure);
- human systems (a.k.a. social infrastructure); and
- environmental systems (a.k.a. natural infrastructure).

However, these are living systems, and change is constant. These systems evolve continuously in response to stress and to take advantage of the opportunities created by all participants.

As detailed in this report, the "realistic, but fictitious" nature of Dystopia makes it ideal not only for modeling and analysis of infrastructure function, but also for the broader investigation of the interaction of technological, social, and environmental systems. More specifically, in the future we imagine Dystopia being used in the following ways.

1. Dystopia can serve as a platform for simulation of technological, social, and environmental system behavior under a variety of "what-if" scenarios.

- We can use Dystopia to assess the ability of these systems to withstand, absorb, and recover from extreme weather events or natural disasters.
- We can use Dystopia to model emergency management operations—such as evacuation, disease outbreak, or humanitarian relief in the aftermath of a hurricane or earthquake.
- We can use Dystopia to study the threat of adversarial behavior from terrorism or state actors.

2. Dystopia can serve as the basis for interactive case studies to teach students about the (often non-intuitive) behavior of interdependent infrastructure systems.

- The network structure inherent to many critical infrastructure systems creates the potential for feedback, cascading behavior, and other dynamics that can be difficult to understand through traditional classroom learning.

- Dystopia provides the opportunity for students to *experience* these phenomena, and to practice decision-making for operations or planning in their presence.

3. Dystopia can serve to benchmark the assessment and design of resilient critical infrastructure systems.

- Islands and installations, in particular, are under pressure from various forces such as impacts of natural hazards exacerbated by climate change (e.g., resulting in new patterns of extreme weather), rapid technological change (e.g., renewable energy and the smart grid), rapid social changes (e.g., aging population), and ongoing economic evolution (e.g., leading to new social and financial pressures on communities).
- Dystopia provides a means to investigate systematically how changes to these systems—such as the introduction of new technologies (i.e., microgrids, renewable energy sources)—affects the performance of these systems under normal circumstances, as well as during emergent scenarios.

4. The rapid development of online gaming platforms creates the potential for novel ways in which Dystopia can leverage open boundaries, complex and unpredictable human and social interactions, and crowd-sourced innovation to maximize the possibility of capturing emergent phenomena. In particular, we imagine using Dystopia to engage humans and surprise, in a couple ways:

- allowing humans to experience surprise for combined technological and human systems; and
- using humans to create surprise for these combined systems

all in the presence of ongoing technological and environmental change.

The development of Dystopia as a platform for these and other forms of experimentation remains a topic of open research.

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