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Building USNA Campus Resilience to Sea-Level Change Effects using X3D Model Publication and Visualization in SPIDERS3D

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Building USNA Campus Resilience to Sea-Level Change Effects using X3D Model Publication and Visualization in SPIDERS3D

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Abstract

Significant modeling work visualized the United States Naval Academy (USNA) campus by postprocessing 3D data scans using X3D modeling techniques for Web publishing. Evaluating visualizations of projected sea-level rise levels due to climate change first led to improved facilities planning for installation resiliency, and then a decision to raise the campus seawall. Potential cost and capability savings are immense. As an important repeatable exemplar, this planning and visualization project offers significant potential value to many Naval facilities. However, although locally viewed visualization analysis provided much insight, permission to release government-owned 3D data and models was never granted. Upon ensuring that all physical-security concerns are addressed, this paper recommends releasing X3D models and relevant data assets for collaborative visualization by USNA, Naval Postgraduate School (NPS), and the Navy. Careful planning of model creation and model sharing offers an opportunity to broadly support the Navy's climate-action planning activities. Additionally, these assets can lead to ongoing applied education and research work by faculty and students at NPS and USNA. This case study provides multiple lessons learned and recommendations for archivable 3D models with broad implications for the defense acquisition process. This paper describes ongoing efforts, continuing to establish a basis for repeatable 3D visualization as a fundamentally important Naval capability.

Motivation

Climate change is a major destabilizing force that affects operational readiness of the U.S. Navy and Marine Corps. Perhaps the most visible aspect of such changes is sea-level rise, which can have a major impact on port and harbor installations. Critical infrastructure is rightly recognized as it "generates, sustains, and postures the force for the fight." Significant imperatives are provided in references Del Toro (2020) and Francetti (2024). Publication of appropriately curated models and documentation of this methodology can further propel Navy resiliency efforts to mitigate future potential climate-change impacts. This emerging, repeatable capability provides significant power for Navy and United States Marine Corps (USMC) installation resilience.

Project Background and Already-Published Products

The USNA developed an Integrated Adaptation Framework to consider potential climate-change impacts from sea-level rise, as shown in Figure 1. Multiple efforts by Naval Support Activity Annapolis (NSAA) led to contracted work for robot scanning of campus building exteriors, adjacent buildings, and utility tunnels to create an integrated set of models, aggregated for Web-compatible publishing using the royalty-free Extensible 3D (X3D) International Standard.

Using these important assets, simple visualization techniques were then added to show expected impact of sea-level rise, as illustrated in Figure 2 and Figure 3. USNA (n.d., 2022, 2023)[1] describe the rationale for this institutional decision with major scope and impact. Understanding the data-collection products, analytic capabilities, and decision process that was undertaken offers significant potential value for other Naval installations as well.

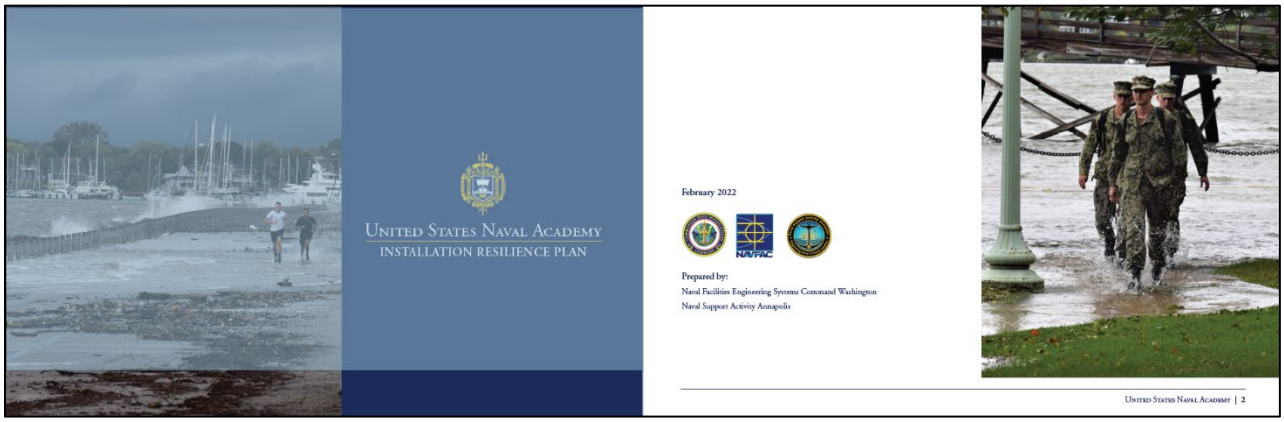

Figure 1. Cover Pages of Publicly Released USNA Installation Resilience Plan 2022 (USNA, 2023)

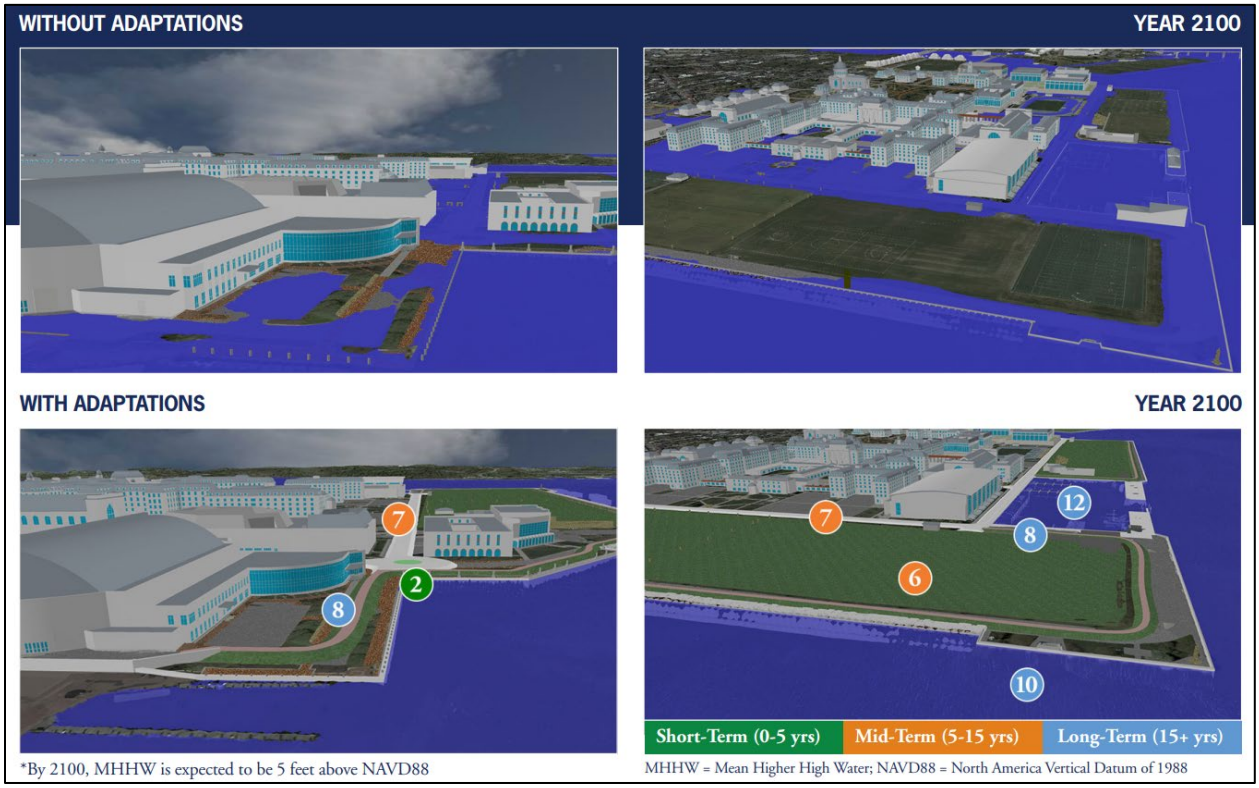

Figure 2. 3D Modeling Portrayals from USNA Installation Resiliency Plan 2022 (USNA, 2023)

[1] The resilience plan, which includes an integrated adaptation framework, project portfolio, and phased execution plan, as well as an executive summary, can be found on the Naval Academy website.

Figure 3. Projected Future Flooding-Level Comparison Using X3D/HTML Modeling, Captured from Demonstration Video

Potential Security Concerns

A number of sensible security concerns have been raised regarding what risks might be associated with the publication of 3D models. Known issues follow, along with corresponding assessments and mitigations for each. Identification of further potential issues is welcome. Following a due-diligence review process during preparation for publication is appropriate for USNA and NPS, each of which hold authorities for handling CUI information. Documenting this process can benefit future ascertainments by other Department of Defense (DoD) installations as well.

Avoiding Unintended Exposure of Sensitive Information

This 3D modeling effort is not cross-connecting databases or exposing any live, critical assets relating to physical security of base facilities. As with publication of any other information asset, content is separated from original sources and then edited or filtered prior to any release.

Avoiding Exposure of Sensitive 3D Models

No campus assets are exposed beyond what is already visible to the many visitors traversing Naval Academy grounds each week. For example, there is no need to publish cabling plans or utility tunnels which conceivably might be exploited by a bad actor. The level of fidelity associated with modeling campus buildings is limited to building exteriors.

Allowing Inclusion of Geospatial Locations

Since any public map can quickly reveal the latitude/longitude location of all facility assets, appropriate internal use of precise geospatial coordinates does not reveal any private or sensitive information.

Allowing Inclusion of Metadata and Appropriate Hyperlinks

The same precautions regarding undue exposure that are used for 3D models need to be similarly applied to accompanying metadata information about those 3D models. Addition of hyperlinks permits users to click on 3D models (buildings, monuments, etc.) to launch an explanatory Web page. Once again, the basic principles of Web design pertain.

Many Related Examples are Available

World Wide Web standards have simplified the creation of hybrid, interlinked, multimedia information sources. The Extensible 3D (X3D) Graphics International Standards enables 3D models to be similarly integrated with other media, effectively making interactive 3D a "first-class capability" on the Web. Of note is that literally hundreds of similar naval facility models are already published via CAC-controlled access to the NAVFAC/EXWC SPIDERS3D system. Similarly the NPS Savage and SavageDefense Examples Archives provide unrestricted or CAC-controlled access, respectively, to numerous additional multimedia 3D models.

Like It or Not: Avoiding a False Sense of Heightened Security

Although prose text, 2D imagery, audio narration, movies, and 3D models provide different presentation modalities and use different formats, they all convey information. If verified information is already available or possible publicly, then hiding government information adds no privacy. Similarly, deliberately remaining unaware of commonly available capabilities does not provide actual security. Security through obscurity should not be used as the only security feature of a system, as explained in "Security through Obscurity" (n.d.).

Deliberate Control of Authoritative Official Confirmation

For a high-profile site like the USNA campus, numerous information assets from varied sources are available publicly. These are sometimes derived from federal, state, public or commercial resources. Recent advancements in technology even enable synthetical AI-produced text, imagery, audio, or 3D graphics. No inappropriate disclosure is expected, based on experienced handling of these matters in accordance with Navy policy.

Technology Basis: X3D and Open Web Standards

Extensible 3D (X3D) Graphics is the open, royalty-free international standard for publishing, viewing, printing, and archiving interactive 3D models on the Web. X3D is used in a great variety of applications by a large number of tools. Key advantages include the following, (with an X3D overview video linked in Figure 4):

a. X3D is an ISO-ratified file format and run-time architecture to represent and communicate 3D scenes and objects.

b. Multiple open-source X3D players allow integration as part of any Web page without requiring special plugins or prior installations.

c. X3D fully represents diverse forms of 3D data.

d. X3D is developed, maintained, and advanced by the non-profit Web3D Consortium in liaison with multiple other Standard Development Organizations (SDOs).

e. X3D is built on the original Virtual Reality Modeling Language (VRML) standard, still viable since 1997, evolving into the considerably broader ISO X3D standard.

f. X3D provides a system for the storage, retrieval and playback of real-time 3D scenes in multiple applications, all within an open architecture that supports a wide array of domains and user scenarios. X3D model import/export/conversion is widely supported.

Immense detail and specific examples on the use of X3D can be found in Web3D Consortium (n.d.-a, n.d.-b), Havele et al. (2024), and th X3D Models of U.S. Naval Academy Campus (n.d.).

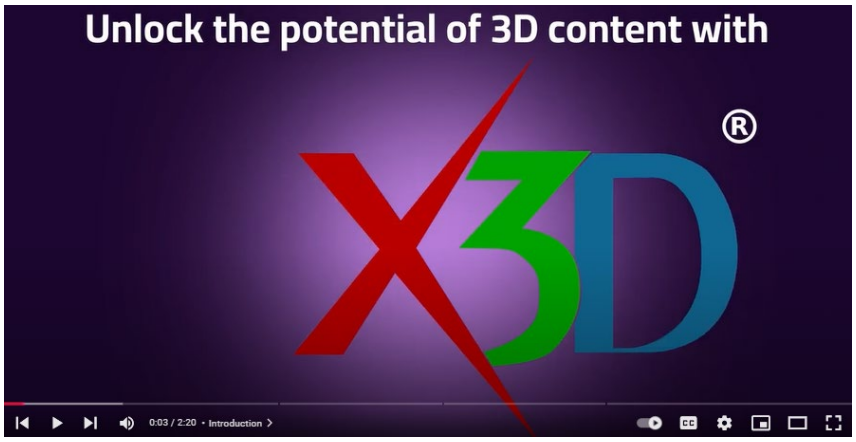

Figure 4. Welcome to X3D Video Shows that X3D Graphics Models are Usable for Multiple Purposes

Of especial interest is that X3D models are portable. X3D Graphics allows modelers to create a Web-based experience, on handhelds or tablets or laptops or big-screen display. This approach is independent of operating systems and reusable by many application libraries. HTML user interfaces can optionally be added to 3D interfaces. Figure 5 illustrates the X3D models for USNA displayed in an immersive environment.

Figure 5. The Virginia Tech (VT) CUBE Walkthrough Video Shows How the Same Unmodified X3D Models Can Also Be Shown in Large-Scale 3D Virtual Environments (3DVEs)

As a potent application for regular collaborative work in 3D environments, the SPIDERS3D collaborative visualization system provides access to shared X3D models to all Navy and USMC personnel, on unclassified networks, using CAC authentication for secure access. A growing X3D model library provides many hundreds of Navy-relevant 3D objects. Multiple locales of interest often include shore-side 3D content of interest, such as pier equipment and exactly spaced pilings retrieved from the official facilities database, calibrated to 1m scale and ready to serve as geospatial context. Figure 6 shows a flexible workflow supporting multiple paths for content preparation and publication, followed by broad subsequent sharing and collaboration. Further details are available in the SPIDERS3D Collaborative Visualization System from NAVFAC/EXWC (n.d.), the SPIDERS3D Program Overview and Collaboration Walkthrough (n.d.), the SPIDERS3D Virtual Sand Table (n.d.), Hall (2024), and Viana et al. (2009).

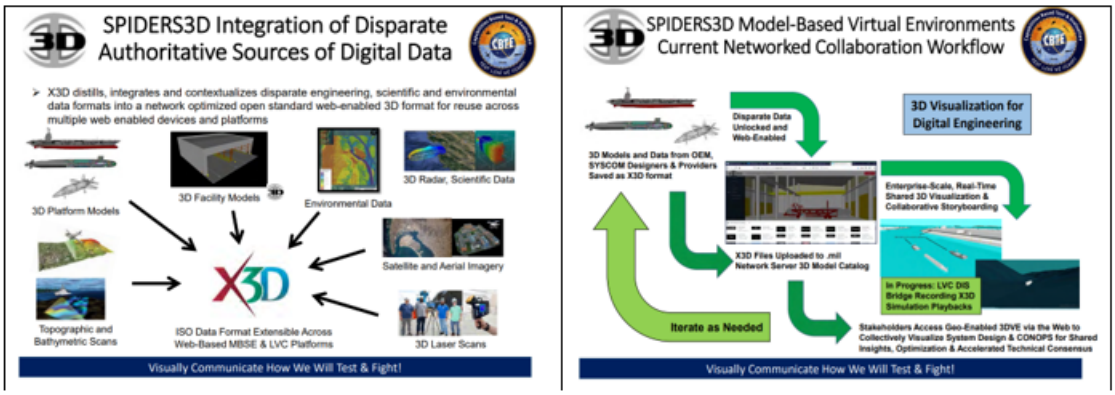

Figure 6. The SPIDERS3D Web-Based Virtual Environment Offers a Collaboration Path Across USN/USMC for 3D Visualization. The SPIDERS3D Overview Presentation and SPIDERS3D Walkthrough Video Describe All System Architectural Elements.

Tools Supporting Model Authoring, Conversions, and Validation

NPS has produced a number of model validation tools that are bundled together in the open-source X3D-Edit authoring tool. This tool suite provides all technical capabilities to perform data ascertainment. Adherence to metadata conventions and canonicalization of text formatting to enable document security and archival publishing. Additional features emphasize model validation, import/export conversions via multiple file-encoding formats, detailed tooltips, reference links, and ancillary software support. Online availability of these open-source assets can be found in Brutzman (n.d.-a, n.d.-b, n.d.c), Brutzman and Daly (2007), *X3D-edit open-source modeling tool*. (n.d.), and Brutzman and Puk (n.d.).

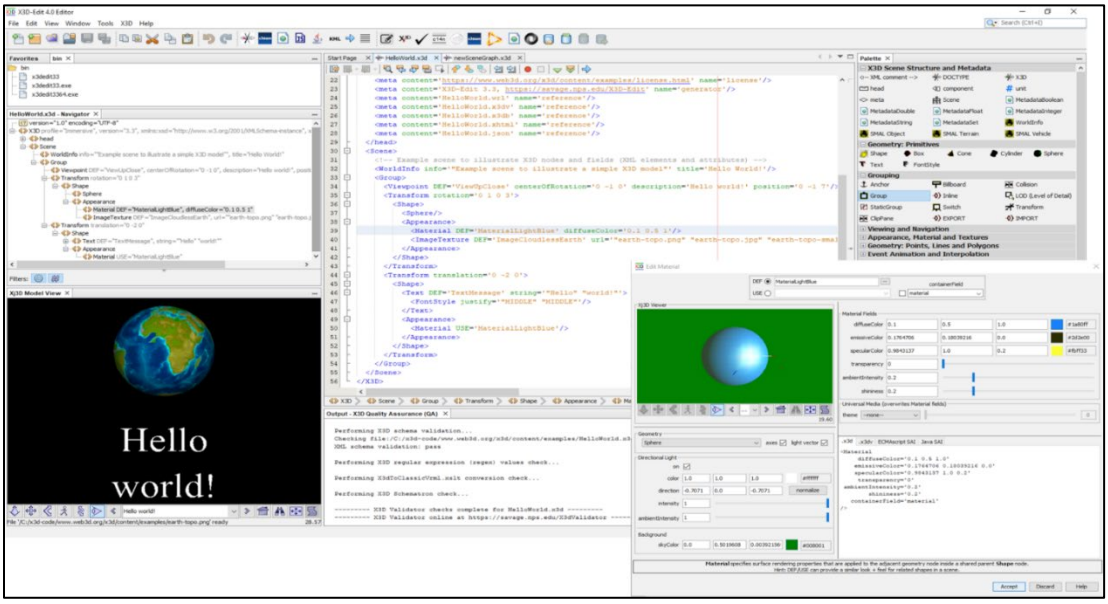

Figure 7. X3D-Edit is a Free, Open-Source X3D Graphics Authoring Tool for Simple High-Quality Authoring, Editing, Import/Export, Validation and Viewing of X3D Scenes

Potential Future Benefits to Navy and Marine Corps

The following examples highlight the versatility and value of a highly precise geospatial, web-based rendering of a naval installation. Multiple benefits can enhance various aspects of installation planning, training, education, and exercises.

Installation Planning

Enhanced Visualization: The 3D rendered scene can be geometrically and geospatially accurate, derived from authoritative models and data sources like CAD, Revit, GIS, and imagery. This allows for better visualization and understanding of the installation layout and infrastructure.

Optimized Model File Sizes: The models are optimized for constrained enterprise network bandwidth, making them accessible to anyone with access to the NAVFAC portal. This ensures that even large-scale models can be shared and viewed efficiently.

Sustainable Digital Engineering: Web-based, open standards enable sustainable cross-SYSCOM digital engineering processes across full platform/program lifecycles. This facilitates long-term planning and development.

Training

Real-time Collaboration: Shareable publication and real-time, web-based collaboration of diverse 3D models enable effective system engineering activities, regardless of the original data source. This is particularly useful for training workshops and exercises.

Comprehensive Training Programs: Training workshops can be conducted at various locations, and web-based handbook training courses can be developed to ensure continuity and accessibility of training materials.

Education

Interactive Learning: Geospatial rendering can be used as an educational tool to provide interactive learning experiences. Students and trainees can explore the installation in a virtual environment, enhancing their understanding of the infrastructure and operations.

Climate Resilience Education: The rendering can be used to educate personnel on climate resilience and adaptation planning. For example, the Climate Action Plan includes comprehensive installation assessments and resilience planning activities that can be tested and evaluated by USNA's Center for Energy Security and Infrastructure Resilience (CESIR).

Exercises

Scenario Planning: The geospatial rendering can be used to simulate various scenarios for exercises, allowing personnel to practice and prepare for different situations. This can include emergency response, security drills, and operational planning.

Performance Tracking: The rendering can be used to track progress and performance during exercises, ensuring that installation readiness is tested and improved continuously.

Strengths Weaknesses Opportunities Threats (SWOT) Analysis

The many useful capabilities shown by the SPIDERS3D system have been hard-earned through years of effort. Some problems (such as misunderstanding Naval needs to share 3D data) remain unresolved. The following strengths, weakneses, opportunities, and threats (SWOT) analysis in Figure 8 summarizes "lessons learned" over the lifetime of this long-running project.

Acquisition Utility of SPIDERS3D, Scenario Planning and Visualization through Archival 3D Model Publication Using the X3D International Standard
Strengths • Unique Department of Defense (DoD) capability with broad Web access secured via CAC. • Open standards to archive data assets, sustained by stable improvements over 30 years. • Growing set of tools, specifications, tutorials, example models with HTML page integration. • Full interoperability with Web standards, handheld devices, both small and large flat-screen displays, XR interfaces and virtual reality (VR) displays, etc. • Expected future compatibility with emerging Metaverse Standards Forum (MSF) capabilities via 3D Web Interoperability Working Group. • Global compatibility with all allied partner nations with added multilingual support possible.
Weaknesses • DoD and individual services have no comprehensive strategy for 3D data or interoperability. • DoD provides negligible institutional support for Standards Development Organizations (SDOs) such as Web3D Consortium or World Wide Web Consortium (W3C). • Data rights are not yet well understood when crafting contracts producing 3D assets. • Open archival standards and interoperability requirements are not yet well defined or applied during the acquisition process.
Opportunities • Demonstration projects show significant repeatable value that deserve recurring efforts. • Web3D Consortium evolves best practices with industry, academia, public, and government. • It is now possible to define suggested contract requirements, metrics, and acceptance criteria. • Common solutions benefit both government and all industry partners, enabling long-term cost-reduction progress in combination with greater equipment interoperability
Threats • Shore-side activities in geospatial planning are often disconnected from operational efforts. • Industry prefers "lockin" to proprietary commercial products, avoiding data interoperability, requiring regular license renewal, with no guarantee that assets remain usable over time. (Sardonic heuristic: "the best time for an opponent to attack is the day after licenses expire.") • Supporting government needs, assets and requirements is often considered contrary to long-term corporate strategies, not considered profitable in absence of government requirements and incentives. DoD commands need to own critical 3D assets, not rent them. • Limited availability and understanding of data interoperability leads to uninformed, mistaken and forced decision making, thus perpetuating counterproductive practices.

Figure 8. Acquisition-Oriented SWOT Analysis Regarding Use of Open Standards for Data Preservation and 3D Model Archiving Using SPIDERS3D and X3D Graphics

Recommendation: 3D Data and Model Review

All relevant X3D model data and raw scans, produced in accordance with Brutzman and Punk (n.d.), are currently held by NAVFAC-tasked contractors. NPS has requested that these important government-funded datasets be delivered to the government. Placing these assets in a trusted, shared location at NPS or USNA for further review by appropriate personnel. Such a review will lead to recommendations for the release of information at either Controlled Unclassified Information (CUI) or unrestricted access. Leadership stakeholders with authority for approving such release include senior personnel at USNA, NPS, NSAA, and NAVFAC/EXWC.

Well-established precedent and practice already exist for such work. For example, the NPS Savage Model Archives are configured for careful handling of both CUI and unrestricted X3D models. Access permissions during the ascertainment can be further granted to USNA faculty, NSAA and NAVFAC personnel, and supporting contractors, as needed. NPS is capable of (and willing to) support hosting these models in a controlled fashion, following all stakeholder guidance, in order to collaboratively perform a security assessment of relevant 3D data and X3D models with other project partners. Successfully executing and documenting such practices holds broader value. Careful attention to detail during this work is likely to further improve candidate best practices and contracts (such as Hall [2024], Viana et al. (2009), and Naval Facilities Engineering Command [2020]) for future Navy/USMC procurement of valid, reusable, standards-based 3D datasets and 3D models.

Next Steps

This work is a multi-year case study resulting in major base improvements. Upon careful review and concurrence regarding what data is releasable, many activities are possible. Future ascertainment activities are interesting and are expected to continue building significant value. Important potential efforts to improve defense acquisition include:

a. Given specific lessons learned (including the incomplete release of X3D assets produced during conduct of Naval Facilities Engineering Command [2020], for example), create specific recommendations for Navy contracting guidelines when procuring and producing 3D models and data assets that deserve either private sharing or public re-use.

b. Addition of USNA campus into SPIDERS3D model archives for CAC-mediated access by personnel across Navy/USMC. Lessons learned can motivate collaborative planning of similar protections for other facilities and installations.

c. Availability for planning faculty and student projects at NPS and USNA.

d. Consider follow-on work regarding climate-change planning patterns for additional bases, possibly hosting a jointly sponsored workshop.

- USNA Center For Energy Security and Infrastructure Resilience (CESIR), https://www.usna.edu/CESIR
- NPS Climate and Security Network, https://nps.edu/web/climate-and-security

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