RESEARCH SHORT

OPPORTUNITIES An exploration of solutions to challenges or problems

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Open-Source and Geo-Intelligence Insights into Environmental Challenges

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Data availability and reliability are key to understanding environmental and human security challenges, but language barriers, people's reticence to speak out, and media repression can limit data collection. To counter these constraints, satellite imagery from the National Geospatial-Intelligence Agency's (NGA) Unclassified Data Lake (NUDL) was used to assess how China's petrochemical industry in the Yangpu Economic Development Zone (EDZ) on Hainan, China's largest island, could impact the region's industrial growth, petrochemical accidents, and natural disasters.

"The Darker the Water Becomes": Information Access

In 2025, a team participating in NGA's Moonshot Labs' Analyst Jam Intelligence Community Centers for Academic Excellence (MAJIC) Challenge—set out to demonstrate that the expansion of China's petrochemical industry during the next decade could put the region at risk of human and environmental security degradation (Fig. 1). An initial risk assessment surfaced little publicly available information—primarily Chinese Government publications offering conflicting information and news reports on petrochemical incidents. One of the most pertinent sources was a press report of Chinese Government attempts to soothe population concerns over petrochemical growth, in which the senior official responsible for water supply on the island of Hainan was quoted as saying, "The more developed the economy is, the darker the water becomes."[1] Although the team found some discussions of Hainan and the petrochemical industry on public forums and in chat rooms, including expressions of concern for the human and environmental sectors, few of those sources could withstand the lens of empirical rigor. Academic articles on China's petrochemical industry do exist, particularly in Chinese journals, but they are largely focused on production, output, and facilitating industrial growth.[2, 3] It was difficult to find academic publications directly related to human security, aside from information on safety standards, that helped in the policy analysis.[4, 5]

Figure 1. NGA Moonshot Labs

Source: NGA

Puzzle Pieces: Open-Source Information

Given the dearth of pertinent Chinese articles, the search was broadened to encompass challenges in the petrochemical industry not unique to China. The United States, for example, experiences one petrochemical incident every three days.[6, 7] And, as the US enforces stricter regulations within these industries, research was uncovered that suggested Chinese petrochemical incidents may be more likely to result in injury and death.[8] These data enabled a comparison of the number of petrochemical incidents occurring in the United States and China, their impact, and the quality of regulations within each country's industry. Using data collected from academic publications on the petrochemical industry in the United States, a list of search terms was created to find Chinese publications on similar topics. This list identified several risk areas of particular importance to China's petrochemical industry, including natural disasters;[9, 10, 11, 12] ocean and groundwater pollution;[13, 14, 15, 16, 17] seafood industries and vulnerable wildlife;[18, 19] and pollutants spilling over into neighboring regions.[20, 21]

Case Study Research Design

The research showed that the Yangpu EDZ on the southernmost island of Hainan has a natural confluence of these risk factors (Fig. 2). The island has robust tourist, residential, and business sectors enmeshed within a functional petrochemical manufacturing area.[22] Because this EDZ plays a prominent role in China's international business economy, a large quantity of published information

about its businesses was available, allowing the identification of human security stakeholders related to tourism, schools, housing, and food industries.[23, 24, 25, 26]

The decision to conduct a case study analysis was supported by more than the chosen region possessing the variables of interest. With limited time and resources, it is challenging to study even a single industry of a single country. Case studies present the opportunity to thoroughly investigate one topic and can function as an excellent pilot study for a more in-depth analysis.

Although this study's findings on the Yangpu EDZ may not be generalizable to the rest of China, they *may* be generalizable to areas that resemble the Yangpu EDZ—a coastal region vulnerable to natural disasters, with a blend of industrial and residential sectors. Future case studies of similar areas in China would have the potential to establish causal relationships between variables. More simply, it could mean other case studies may also find data from the areas as this study did—particularly business records and industrial development plans.

Figure 2. Satellite image shows the vulnerability of the Yangzu EDZ to natural disasters.

Yangpu Bay: NASA Earth Observatory, image by Lauren Dauphin, May 6, 2020, https://earthobservatory.nasa.gov/images/147129/a-sandy-flower-in-the-pacific.

To assuage concerns over relying on Chinese sources for the case study, data from the business sector was added to the research from academic publications, news articles, and government reports. Combing through business records published by *Dun & Bradstreet* identified the major players in the EDZ's petrochemical industry. The three largest petrochemical stakeholders in the area are all government-sponsored businesses; indeed, they were among the largest suppliers of China's petrochemical precursor reserves.[27, 28, 29]

It was determined that investigating the companies operating within the EDZ and collecting public dialogue on the development zone would help contextualize its significance to China's economic agenda. Because the EDZ welcomes many international businesses, finding companies within the scope of the study that operated within the zone was relatively easy. The publicity around the port's development also made it easy to collect information from Chinese state media highlighting the EDZ's global role—promoting not only China's domestic objectives but the country's growing international business presence. The collected information included statements and publications from President Xi Jinping and other political entities, reports on diplomatic missions, and press releases about the development of cultural and educational centers. Although state-produced dialogue sometimes challenges credibility, collecting this information adds context to how China presents itself—and the EDZ—to the world.

Organizing the Puzzle: Geospatial Intelligence

Participating in the MAJIC Challenge provided access to NGA's satellite imagery repository, NUDL, allowing the team to pair the case study and policy analysis with geospatial intelligence (GEOINT)

(Fig. 3). Synthetic aperture radar (SAR) imagery from the ICEYE collection* provided images of the case study region to ensure depth of coverage. The highest-resolution images were selected for analysis.

The most useful element of SAR imagery was its ability to distinguish between types of materials and objects. For example, plastics and round objects appear as dark, irregular masses, while metallic structures give off stronger radar reflections and appear bright and linear. Although the port is not complete, the SAR imagery pinpointed construction zones of what was believed to be a new petrochemical sector next to a residential living area—far from where it was supposed to be, according to a development plan map of the EDZ.[30] This deviation from the official development plan risks the human and environmental security at the core of this investigation.
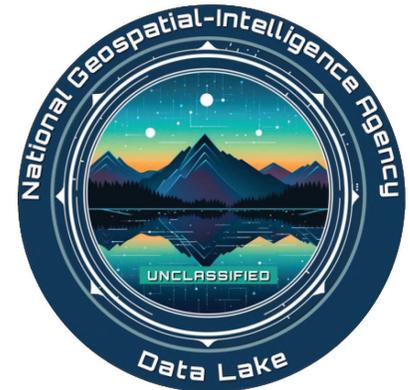
Figure 3. NGA Data Lake seal

Source: NGA

To conduct a true analysis of the satellite image, Google Earth was used to explore the areas not covered in NUDL's SAR image. Doing this uncovered the names and types of businesses, including hotels, grocery stores, entertainment venues, and petrochemical stakeholders. Because Google Earth contained imperfect information, particularly when geolocating businesses, the businesses' websites were verified, and addresses were cross-checked using records from *Dun & Bradstreet.* Because Chinese state media has a long history of censoring news and downplaying disasters that occur,[31] it was important to ensure each piece of data was cross-referenced and confirmed by other sources. Integrating the SAR image with Google Earth and business records enabled the team to triangulate its target sectors to establish the validity of the findings.

The Final Picture: Policy Analysis

Data from open-source policy documents and publicly available government reports informed the study's policy analysis of Chinese regulations surrounding the petrochemical manufacturing industry. The effort focused on understanding how Chinese authorities regulate petrochemical manufacturing—particularly regarding accident prevention, environmental oversight, and industry compliance. Because the EDZ was the centerpiece of the Hainan Free Trade Port (Fig. 4), a higher number of English-language policy documents intended for foreign investors were found compared to other areas of China, which significantly aided the review process.

Figure 4. Hainan Free Trade Port

Source: Shutterstock

Several challenges emerged, however. First, because the English-translated materials were designed to attract investors, they emphasized economic opportunity over environmental or human security risks—it was necessary

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* To learn more about the ICEYE mission, visit https://www.iceye.com/en-us/.

to read between the lines to identify regulatory gaps or areas of weak enforcement. Second, some domestic-facing policies and technical standards were only available in Mandarin, requiring the use of translation tools to interpret them. Basic translation software was used to interpret key phrases or policy feedback in online public forums and government websites, which introduced limitations in accuracy and context. Although the EDZ case study offered unusually accessible documentation in English, ultimately this analysis was shaped by what was available and what was left unsaid in policy narratives meant for international audiences.

Implications: Maintaining Academic Rigor in Security Studies with an Information Deficit

Ultimately, the risk assessment and policy analysis found that China's policymakers and industry professionals favored economic growth over adhering to human and environmental security protections. Sources further suggested that independent oversight and third-party auditing agencies could help alleviate this problem. Careful auditing would also strengthen the study of human and environmental security because publicly available information—monitored by an independent system of checks and balances—could increase and validate data.

The lack of available data strongly suggests that improving data access is key to China's ability to improve human and environmental security. Reducing the lack of real-time environmental monitoring systems, which limit the government's ability to track pollution levels and detect violations, can expand public transparency through open-access pollution databases. Enhancing accountability and citizen engagement in environmental policy would likely expand the pool of resources available to academic researchers trying to publish assessments that can withstand empirical tests of validity and reliability.

Integrating satellite imagery and tracking geographic changes over time can help fill in the gaps for those studying topics in the security field where information might be scarce or inaccessible. The ability to identify visual examples of environmental pollution and violations of existing policies regulating petrochemical manufacturing exposed gaps between Chinese state publications and the findings of academic research. Ongoing work exploring human and environmental security is key to finding creative ways to solve information-access challenges and encourage others to pair their scholarly investigations with information from both geospatial and open-source venues.

Recommendations for Human and Environmental Security

Challenge: Sources were limited. A Hainan economic report from 2023 noted that petrochemical plants in the Yangpu EDZ frequently exceed permitted pollution levels despite existing laws that mandate strict wastewater treatment processes.[32, 33] Public access to petrochemical industry monitoring data, however, was restricted,[34] and it was even more challenging to find information about noncompliant businesses.[35]

Recommendation: The introductory and concluding sections of academic publications often contained valuable references to other academic and nonprofit sources of information, particularly regarding environmental monitoring infrastructure, safety standards enforcement, and the identities of those responsible for lobbying and policy change. Academic publications offered policy suggestions that were particularly useful to analyze. Public forums, although imperfect sources of data, talked about the population's desire for formal grievance mechanisms and citizen-led reviews that would improve trust and transparency, which provided valuable context for other data.

Challenge: Although it was clear from policy documents that sensitive marine habitats, such as those in the Yangpu EDZ, were vulnerable to industrial discharge,[36] this study was unable to identify how the Chinese contain, label, or dispose of toxic petrochemical refinement byproducts.[37]

Recommendation: Despite struggling to find specific details on petrochemical material safety standards, a few reports of egregious violations suggest either insufficient oversight or inadequate monitoring.[38] For this, GEOINT was particularly handy. Combining Google Earth with business records enabled finding not only petrochemical manufacturers and related businesses, but also visual examples of possible violations such as wastewater dumping and improperly monitored run-off and retention ponds.

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